Light and Lighting

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Contents

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Student Efforts

THIS month we publish some of the papers read by student members of the Illuminating Engineering Society at an informal meeting earlier in the year. Students are often "backward in coming forward" to give expression to their ideas, and accounts of their work in the field of their choice, although what they have to say may be of value not only to fellow students but also to the " old hands." They should be encouraged to offer papers for presentation to the I.E.S. or for publication in appropriate journals. The first Dow Prize Competition attracted many entries but the proportion of students of illuminating engineering was not as high as we think it should have been. The Silver Jubilee Award given by the I.E.S. only to students is rarely applied for, and this reluctance to obtain what should be a coveted distinction is surprising. It is true that the number of students of illuminating engineering is not large, but we cannot believe that they are unadventurous nor that the proportion who have something worth communicating to others is any smaller than it is in other student groups.

Notes and News

I.E.S. Programme

The I.E.S. programme of meetings to be held in London and in the Provinces during the session beginning in October has just been issued. The papers to be given in London cover a fairly wide range of practical interior lighting subjects; the only laboratory paper would seem to be one on flicker in relation to interior lighting, but which will, no doubt, draw a full house of practising lighting engineers. We are glad to see included a paper on flameproof lighting, a subject which is due, perhaps overdue, for discussion. The discussion on the design of lighting fittings should be interesting particularly, so we understand, as it is to be opened by some well-known designers and critics. The snag with so many of these discussions arranged by the I.E.S. is that few of the people who attend them seem to go prepared to take part in the actual talking—the best part of the discussion so often takes place later in the Savoy Tavern. Lighting fittings is a subject which ought to be good for at least a couple of hours of good ding-dong stuff. Incidentally we see that J. N. Hull, who left this country a few years ago to join the Dominion Physical Laboratory in New Zealand will be in this part of the world next winter and will be giving a talk.

In the programmes of the Centres and Groups we notice a few new names and a few new subjects, or perhaps new twists to old subjects. An interesting meeting should be one arranged by Birmingham on stage lighting from the producer's point of view, which will take place in the Crescent Theatre.

We notice that no one has repeated the successful experiments carried out by one or two Centres, and London, last year in having a meeting at which students give short papers. It is doubtful if similar meetings can be held two years running in the same place, but we should have liked to see more such meetings arranged. There is still too much reliance on a few speakers who do a tour around the country; new boys need encouraging—if they are afraid of speaking before "experts" then they should be reminded that experts are only people who realise how little they know—and where lighting is concerned that is pretty true.

Next year we have the fourth summer meeting, in Southport from May 18 to 21. Readers should note the date now; from what we gather the programme is likely to be better than ever, the accent of the papers being on usefulness to the lighting engineer and those who have to apply and use good lighting.

We also gather that the second competition for the Dow Prize will be held next year; it is, maybe, a little early to be writing about it, but younger readers might well begin to think of getting to know architectural students so that they can pair up with them when the time comes.

Farm Lighting

Some time ago we commented on electricity for farms, and ventured to suggest that it would be a mistake to assume that every farmer in the country knows enough about the benefits of electrification to be clamouring for a supply at the present time. The publications of the British Electrical Development Association do much to make information available to farmers, and their latest publication, Farm Electrification Handbook No. 3 on Farm Lighting is a very useful guide to the design of farm lighting installations. Its primary purpose is to put forward a reasonable standard of farm lighting and to provide a common basis of action for all concerned with farm lighting, whether as user, electrical contractor or agricultural engineer.

Nearly 150,000 farms in Great Britain

now have an electricity supply, nearly twice as many as in 1947. As most farmers and farm workers are accustomed to traditional farm lighting by oil or pressure lamps it is not surprising that few of them are critical in lighting matters, since even poor electric lighting is better than that which they are used to and, of course, it brings with it the advantage of switch control.

There is bound to be a tendency on the part of farmers to regard a standard of lighting which is normal in other industries as being unnecessarily high on a farm, particularly when lighting is first installed. The importance of the agricultural industry, however, and the increasing shortage of manual labour are such as to require that the utmost use be made of methods of improving working efficiency and for reducing calls on human effort. Farm modernisation and mechanisation impose much greater visual demands on farm workers than formerly; new skills have to be acquired and the use and servicing of expensive equipment cannot be restricted to daylight hours. (We recall that Ward Harrison pointed out recently that if a worker is expected to operate an expensive machine he might as well be given sufficient light to enable him to look after it.) As the E.D.A. Handbook states, a properly planned lighting installation need be no more expensive than a haphazard one; with the present shortage of farm labour it is essential not only that working conditions should make for efficiency but that they should be comparable with those of other kinds of work in order that farming will continue to attract new entrants. To this end lighting plays a very important part.

Incidentally, since our last note on farm lighting, we find that our friends on Exmoor are most anxious to have electricity laid on; they have discovered television. As there is no supply available they install their own plant, which they find not only enables them to enjoy TV but will also give them enough light to get around after dark. To hasten the progress of farm lighting we suggest that those firms who make both TV sets and lighting equipment send enterprising salesmen to Exmoor to sell each farm a TV set. If B.E.A. is quick enough they might get in before the generating plant salesmen.

Courses in Illuminating Engineering

Courses for the City and Guilds examinations in illuminating engineering during the coming winter will be held in London and Belfast. Courses will also be arranged in Leicester and Nottingham if sufficient students are forthcoming.

Courses in London will be held at the Northampton Polytechnic and the Borough Polytechnic. Courses for the Intermediate and Final Grades begin at the Northampton Polytechnic on September 28, and students are asked to enrol on the 21st or 22nd. Courses for the Intermediate and Final will also be held at the Borough Polytechnic.

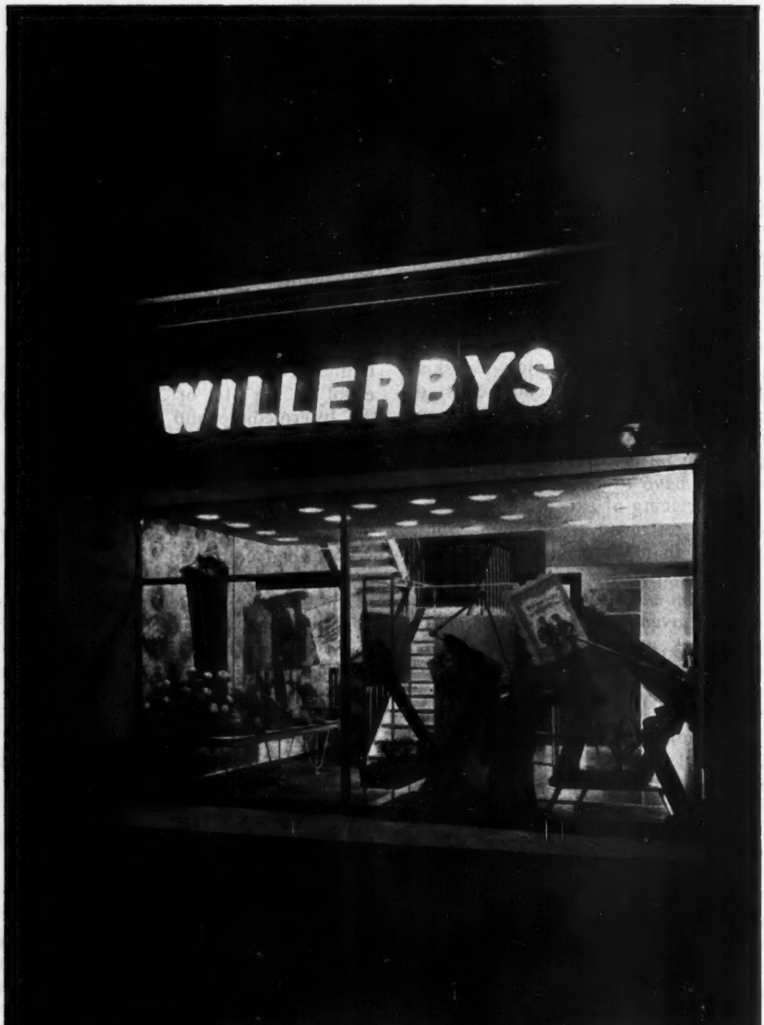
At Belfast College of Technology a course to cover the Intermediate Grade will be held; a course for the Final Grade will be held if there is sufficient support.

A special course of 12 weekly lectures on Modern Discharge Lighting will begin at the Borough Polytechnic on September 30 (fee £2 10s.). The lectures will be given by well-known authorities on discharge lighting. Details of the course can be obtained from the Dept. of Electrical Engineering and Physics at the Polytechnic.

Students in Nottingham wishing to take the course for the Intermediate examination should apply to the Nottingham and District Technical College between September 14-17.

Coronation Lighting

We have received a number of requests for additional copies of our August issue, which dealt exclusively with the recent Coronation floodlighting. As this issue is the only souvenir of its kind of the Coronation, or indeed of any Coronation, many readers wish to send copies to friends at home or overseas. We are naturally pleased that our efforts were so well received.



Willerbys' new shop at Southampton.

Lamps for Industrial Lighting

By F. J. G. CLACK and J. S. HEMMONS

When the lighting of new industrial premises or the relighting of old premises is planned, the choice of light source is one of the first things to be considered. The following article describes the characteristics of available light sources.

The most suitable type of light source inevitably depends on circumstances and the relative importance of the various characteristics of the different types of light source available. This article points out which characteristics are of greater or lesser importance in various situations, and it is hoped that thereby it may help those who have to design or approve designs for industrial lighting installations.

Survey of Characteristics to be Considered

We shall confine our considerations to general lighting, as opposed to local lighting, and before proceeding it may be as well to make a list of the lamp characteristics which must be considered:—

(1) Cost of fittings and auxiliary gear.
(2) Cost of lamp.
(3) Lamp wattage.
(4) Lamp efficiency.
(5) Lamp life.
(6) Lamp light output maintenance (lumen maintenance).
(7) Size of light source.
(8) Brightness of light source.
(9) Colour appearance of lamp.
(10) Colour rendering properties of the light.
(11) Resistance of the lamp to atmospheric conditions.
(12) Influence of ambient air temperature and draughts on the light output of the lamp.

The object of a general lighting scheme is usually to provide the necessary light at the working plane as economically as possible.

Interiors may be classified according to the mounting height of the lamps, and for convenience we will call heights of less than 20 feet above the working plane Low Mounting Heights, those of more than 40 feet High Mounting Heights (High Bays) and those between 20 feet and 40 feet Medium Mounting Heights.

High Mounting Heights

The greater the mounting height in relation to the length and breadth of the working plane, the more concentrated must be the light distribution from the fitting if unnecessary loss due to absorption by walls is to be avoided. This calls for a small size of light source which will allow a high degree of light distribution control with a reasonably small fitting. Sources of high light output are an advantage as with these fewer fittings are required and although high light output and small source size mean high brightness, direct glare need not be serious because the sources are well away from normal lines of sight.

That high lamp efficiency is an advantage goes without saying and as lamp colour appearance and colour rendering properties are usually of minor importance in high bays, mercury discharge lamps are frequently used. It is interesting to remember, in passing, that a lack of red light is of little consequence in a place where there are no objects capable of reflecting red light, as is often more or less the case in high bays. Long lamp life is an advantage so long as it is associated with good light output maintenance.

Low Mounting Heights

The lower the mounting height the broader must be the light distribution from the fitting to obtain reasonable uniformity of illumination without an excessive number of fittings. A broad light distribution is not unduly wasteful when the ratio of mounting height to the length and breadth of the working plane is small, as a high proportion of the light will reach the working plane without being reflected by either walls or ceiling. This type of light distribution can be achieved with any size of source and as the light sources will inevitably be fairly close to normal lines of sight, it is desirable to have large sources of low brightness. If the source itself be of high brightness it must be enclosed in a diffusing bulb or fitting. These requirements generally lead to the use of many lamps of relatively low wattage, fluorescent tubes being popular.

Even when sources of comparatively low brightness are used there is risk of glare with low mounting heights, and it is important to allow some light to reach the ceiling so as to provide a fairly bright background to the light sources themselves.

High lamp efficiency, long lamp life and good light output maintenance are just as desirable with low as with high mounting heights.

At low mounting heights the lamps are more obvious and their colour appearance becomes more important; too "cool" or too "warm" an appearance may have an undesirable psychological effect. Fairly good colour rendering is usually important in interiors with low mounting heights by reason of the kind of work carried on in such places.

Medium Mounting Heights

With mounting heights between 20 and 40 feet the situation is obviously intermediate between high bay and low bay. Fittings giving a fairly concentrated light distribution are desirable on grounds of economy. There is, however, some risk of glare, and frequently low brightness sources such as hot or cold cathode fluorescent tubes are chosen in spite of the heavy initial expenditure entailed and the fact that concentration of light distribution is only practicable in the plane at right angles to the length of the tubes. Cold cathode tubes are often preferred to hot cathode at medium mounting heights because their longer life means less frequent tube replacement, an important consideration on account of the large number of tubes required.

Whatever lamps are used it is important to spare some light to illuminate the ceiling or roof, but it is not necessary to have such a high proportion of upward light as with low mounting heights.

Lamps and Their Characteristics

There are four main classes of lamp to be considered for industrial lighting—mercury, sodium, fluorescent and tungsten. It is now widely appreciated that illumination levels of at least 10 to 20 lumens per square foot on the working plane are desirable in most places, as opposed to the 2 to 5 lumens per square foot provided by early tungsten installations, and it can be said that the use of tungsten lamps alone in large installations is becoming less and less favoured, purely on the score of lighting economics.

The four main groups of light source are further divided for the purpose of this article as follows:—

(i) MA and MAF mercury lamps.
(ii) MB and MBF mercury lamps.
(iii) MAT and MBT dual mercury/tungsten lamps.
(iv) Fluorescent tubes—hot cathode and cold cathode.
(v) Sodium lamps.
(vi) Tungsten lamps.

Each of these sections will be dealt with individually and in section (ii) new colour correction techniques and the possibilities of internal reflector MB mercury lamps will be considered. In section (iii) mention will also be made of mercury and tungsten lamps used together in blended installations, as this is becoming an increasingly favoured technique.

All discharge lamps require a ballast to limit the discharge current to its correct value, owing to the lamp's negative resistance characteristic. In the case of mercury lamps and hot cathode fluorescent tubes this ballast takes the form of a choke when operating on AC supplies or a resistance if the lamps are run on DC. In the case of sodium lamps and cold cathode fluorescent tubes a step-up leaky-flux transformer is used to provide the high starting voltage as well as the necessary impedance.

(i) MA and MAF mercury lamps

(Glass discharge tube loaded above 10 watts/cm. of arc length) 250 and 400 watt MA; 400 watt MAF.

As immediate successor to the tungsten lamp for industrial lighting, the MA type of mercury lamp can be regarded as the typical

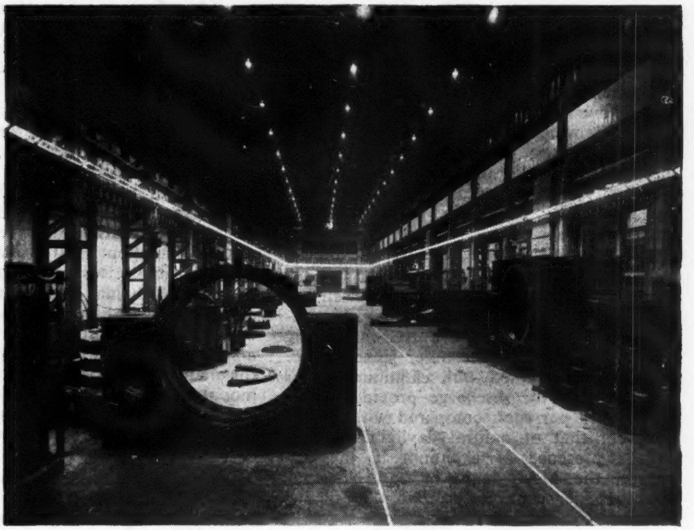


Fig. 1. *The G. E. C. Heavy Engineering Works, Witton, Birmingham.* 1,000 - *watt MB/V mercury lamps mounted* 20 *ft. above the floor provide about* 20 *lm./ft.*^{2}.

light source. It has now been in use for some 20 years and has established a reputation for reliable service with good life and good lumen maintenance. The MAF mercury fluorescent lamp is a modification of the ordinary MA type, and it is used when improved colour rendering properties are required.

The MA lamp is available in 250 and 400 watt ratings, and the standard vertical burning types have average throughout life efficiencies of 32 and 36 lumens per watt respectively over a nominal life of 3,000 hours. It is a well-known fact that the life of a discharge lamp is to some extent affected by switching frequency, and it is generally found that with long periods of continuous burning this average life rating is very conservative indeed.

There are four distinct types of MA lamp, designed for different conditions of operation:—

MA/V—the most widely used lamp, which burns vertically cap up, or horizontally with magnetic deflector for arc control. Average throughout life efficiencies—250 watt MA/V, 32 lm./w., 400 watt MA/V, 36 lm./w.

MA/V Hard Glass—this lamp has an outer jacket of harder* glass than that of the MA/V, and is suitable for use in corrosive atmospheres under similar burning conditions. Average efficiencies are as for ordinary MA/V type.

MA/H—the outer jacket is of hard glass and the lamp is designed for horizontal burning without magnetic deflector. Average throughout life efficiencies—250 watt MA/H, 29 lm./w.; 400 watt MA/H, 33 lm./w. MA/U—this lamp falls between the MA/V Hard Glass and the MA/H lamps. In general, when burned vertically its efficiency compares with that of the MA/V lamp, and when burned horizontally with that of the MA/H lamp.

In atmospheres containing sulphurous fumes, even when the concentration of sulphur dioxide is very low, there is the possibility of chemical attack on the glass jacket resulting in the production of a whitish deposit of sodium sulphate. This "sulphating" effect is fairly frequently encountered and in its early stages is of little consequence. Careful measurements have shown that its presence results in slight diffusion of light from the lamp, but that the total light output is reduced by a negligible amount.

It should be borne in mind that a corrosive atmosphere is almost always a smoky, dirty atmosphere and the sulphate deposit provides a key for collection of dirt on the lamp jacket. Under such conditions a

* Hardness is a term used in glass technology, to denote that a glass has a high softening temperature; in practice this quality is often associated with low coefficient of thermal expansion and high resistance to both thermal shock and chemical attack.

regular cleaning schedule of lamps and fittings is essential for maintaining the light output of the installation.

The MA/V lamp has a soft glass jacket and when sulphating is rapid it is advisable to use one of the lamps with an outer of hard glass which is more resistant to attack. In severe cases, the sulphating of a soft glass outer results in crazing which may make cleaning difficult, if not impossible, and eventually results in fracture of the outer jacket.

The 400-watt MAF lamp was introduced to meet the demand for better colour rendering. The MA mercury discharge produces a negligible amount of red radiation and the use of a red-fluorescing phosphor applied to the outer jacket of the MAF lamp, coupled with cadmium colour correction of the discharge provides a red ratio* of 5 per cent. compared with 12 per cent. for that of natural daylight. Owing to the presence of cadmium in the discharge, the MAF lamp has an efficiency about 11 per cent. lower than that of the ordinary 400-watt MA/V lamp.

Since the phosphors at present in use have to be operated at a fairly low temperature it is necessary for the outer jackets of the fluorescent lamps to be larger than those of the ordinary types. The 400-watt MAF has a special "isothermal" jacket, so designed that its operating temperature at any point does not rise above 160 deg. C.

(ii) MB and MBF mercury lamps.

(Quartz discharge tube loaded below 100 watts/cm. of arc length) 80, 125 and 1,000-watt MB; 80 and 125-watt MBF

Whilst the MA lamps are probably the most widely used industrial light sources at the moment, the MB lamps will gain much popularity in the future with the development of high wattage types, advances in colour correction technique and the introduction of internal reflector types.

The MB lamps operate at a higher temperature and pressure than the MA types and have a discharge tube of quartz. The 80- and 125-watt lamps have been on the market for 16 years and are widely used in normal industrial installations at low or medium mounting heights. The nominal life is 2,500 hours, and the average throughout life efficiencies are 31 and 33 lumens per watt respectively. Owing to the high brightness of the arc these lamps are fitted with pearl bulbs which reduce the apparent brightness of the source to about 60 candelas per square inch.

A recent addition to the range is the 1,000-watt MB lamp, which was first marketed some three years ago. It is suitable for mounting at heights of 40 feet or more in high bays and for area lighting out of doors. In its more usual form it requires an A.C. supply of about 400 volts and is thus operated across two phases of a three-phase supply. With an average throughout life efficiency of 48 lumens per watt, a nominal life of 3,000 hours and excellent lumen maintenance it is proving a good light source for many installations having the necessary mounting height. Its use effects a considerable economy compared with the 400-watt lamp from both installation and running cost points of view.

A mains voltage 1,000-watt lamp has recently appeared and is, of course, convenient if high voltage supplies are not readily available. At present it has a rather lower efficiency than that of its high voltage counterpart and has a nominal life of 2,000 hours.

The 80 and 125-watt MBF lamps are similar in general detail to the 400-watt MAF lamp, in that a red-fluorescing phosphor is applied to the inner surface of the outer bulb. The MB discharge produces a higher proportion of red radiation than the MA type, and further colour correction by addition of cadmium to the discharge is not required. The average throughout life efficiencies, as in the case of the standard lamps, are 31 and 33 lumens per watt.

Improved colour correction of MB lamps is being intensively studied both in this country and abroad, and the earlier phosphors are now being superseded by various new powders with greatly improved properties. They are more efficient in converting ultra-violet energy from the discharge into visible light, and their pure white body colour gives the lamp a far more attractive appearance. Being more temperature-stable than the earlier types the use of a smaller bulb is possible and, as a result of this, colour correction of the higher wattage MB lamps has become practicable for the first time. As yet it is too early to assess the individual merits of these new powders, but as a class they represent a great advance in colour correction technique.

An added advantage of this development

* Red ratio is defined as the percentage of the total lumens transmitted by a Wratten 25 red filter. It must be borne in mind that the percentage of red light is not the only criterion of good colour rendering. In the case of mercury lamps it merely serves as a comparative measure of the improvement effected by colour correction.

is that colour correction is provided with no loss in efficiency—it may even be that a slight gain will eventually be realised. Successful colour correction may well lead to an extension of the range of MB lamps available in this country, to meet a demand for lamps between the existing ratings of 125 and 1,000 watts. Already the new type of 125-watt lamp is being marketed in Europe and 400- and 1,000-watt versions are being widely advertised in America. Much interest is being shown in America in the internal reflector MB lamps. The comparatively small source permits accurate control of the light distribution, and dirt collection is at a minimum on the horizontal bulb face when the lamp is operating in its normal cap-up position. As this type of lamp could be used without a fitting—or with some very simple shield to protect it from condensation or rain splash if necessary—the greatly reduced capital cost of installation will sometimes offset the rather higher cost of the lamp.

(iii) MAT and MBT dual mercury/tungsten lamps

300 and 500-watt MAT; 160 and 250-watt MBT.

The dual lamp consists of a tungsten filament ballast operating with a mercury discharge, and hence can be run direct from a mains supply without use of external control gear. The red ratio is of the order of 8 per cent. and there is the further advantage that an appreciable amount of light from the filament is available immediately the lamp is switched on.

The MAT lamp employs an MA inner connected in series with the tungsten filament. During the running-up period the entire filament is in use, but a bi-metal switch short-circuits part of the filament as the fully run-up condition is reached.

The MBT lamp has an MB inner and the entire filament is in service during starting and throughout operation. Switching out a portion of the filament after starting is unnecessary in view of the shorter running-up time.

In large works blended installations of high wattage mercury and tungsten lamps are being used in cases where fairly good colour rendering is required. The conflicting requirements of high efficiency and ease of colour discrimination must be carefully weighed up, and a compromise must be struck between high efficiency mercury lamps with long life but poorer colour rendering and low efficiency tungsten lamps with short life but better colour rendering.

The table serves to show the more important values to be considered from the point of view of life, light output, efficiency and colour rendering. These figures show clearly that increase in the red ratio is only obtainable at the cost of reduction in overall efficiency. Similar values for MAF, MAT and MBT lamps are also shown.

Discharge Lamp Characteristics

Lamp or Lamps	Average life, hours	Average throughout life: lumens	Average throughout life: efficiency lm/w	Red Ratio (approx.), per cent.
1000 watt MB/V	3,000	48,000	48	2
1000 watt MB/V 1000 watt tungsten	3,000 1,000	64,800	32.4	7
400 watt MA/V 1000 watt tungsten	3,000 1,000	31,200	22.3	11
1000 watt tungsten	1,000	16,800	16.8	20
400 watt MAF/V	2,500	12,800	32	5
500 watt MAT/V	2,000	10,500	21	7.5
250 watt MBT/U	2,000	4,250	17	11

(iv) Fluorescent Tubes

MCF hot cathode—8 ft. 125 watt
5 ft. 80 watt
4 ft. 40 watt
cold cathode—9 ft. 6 in., about 70 watt and other sizes.

The use of fluorescent tubes, both hot cathode and cold cathode, has become increasingly popular for the lighting of low and medium bay industrial interiors during the past 10 or 15 years. Their high average throughout life efficiency of about 30 to 40 lumens per watt and long life of 5,000 hours for the hot cathode and 15,000 hours for the

Fig. 2. The Calico and Jubilee Mills of Ahmedabad, India. 80 - watt MCF fluorescent tubes mounted about 11 ft. above the floor provide 22 lm./ft.²

cold cathode type are obviously attractive, and their low brightness of about two to five candelas per sq. in. and good colour-rendering properties make them particularly suitable for low mounting heights. Their chief drawback is the relatively high cost of the fittings and auxiliary gear as the low light output of the individual tube necessitates such a large number of tubes.

Cold cathode tubes light immediately on switching and hot cathode tubes may be made to light almost instantly by using "instant start" circuits in place of the more usual "switch start" circuits. The slight delay with switch-start circuits is generally of little import in factory installations.

Both hot and cold cathode tubes are available in a variety of colours, and intending users must select the one that suits their purpose best, remembering that the colour appearance of the lighted tube and its colour rendering are two separate and more or less independent characteristics. Although a few industrial interiors such as colour printing shops require colour rendering akin to that of natural daylight, and use the fluorescent tubes known as "Colour Matching," really good colour-rendering properties are not usually necessary and "Daylight" or "Warm White" tubes are adequate. These have the advantage that the moderate sacrifice of colour-rendering properties is accompanied by an increase in efficiency of about 45 per cent. "Colour Matching" has an average throughout life efficiency of about 28 lm./w. compared with some 40 lm./w. for "Daylight" and "Warm White" tubes. If somewhat better colour rendering than that provided by "Daylight" and "Warm White" is required "Natural," which has an average throughout life efficiency of about 34 lm./w., may be used.

The arc in a fluorescent tube is not thermally insulated from the surrounding air, as in the case of other discharge lamps, and ambient air temperature has an appreciable effect on the light output of this type of lamp. It gives its maximum output with an ambient air temperature of about 20 deg. C., and if temperatures of less than about 5 deg. C. are likely to be encountered it is advisable to use enclosed fittings.

Draughts aggravate the situation at low temperatures especially in the case of the long cold cathode tubes which are liable to darken towards the ends. In exposed positions fluorescent tubes, and especially those of the cold cathode type, should be in enclosed fittings or at least protected from draughts as much as possible.

(v) Sodium Lamps

45-, 60-, 85- and 140-watt

The very high efficiency of the sodium lamp is offset by its very poor colour rendering properties which normally preclude its use for interior installations.

The lamp consists of a low-pressure discharge tube, bent in the form of a U and constructed of a special ply glass with a

(Continued on page 353)

Illumination Calculations for Installations using Long Linear Light Sources

By P. M. EXCELL*

The two usual methods for the calculation of illumination are the point by point method and the lumen method.

Provided an exact knowledge of the source characteristics and the laws governing the relation between these characteristics and the plane illumination are known, then the point by point method will enable a true evaluation to be made of the quantity and variation of direct illumination falling on the working plane. In this method a series of points are selected and the illumination produced at each point by each individual fitting is calculated and the results summed. The method suffers from the disadvantage of neglecting the effects of inter-reflections.

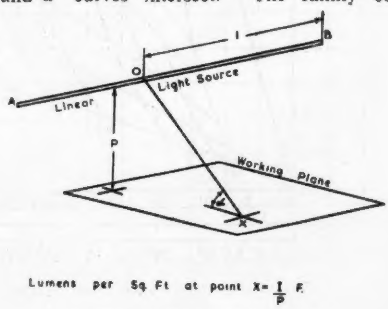
In the case of sources which are small compared with their perpendicular distance "p" from the working plane (see Fig. 1), the inverse square law can be applied and illumination values simply and quickly calculated. With a source of maximum dimension greater than 0.2 p, more complicated calculations are necessary. Continuous rows of fluorescent lamps fall into this latter category and several methods have been developed for the purpose of such calculations.

On the other hand the lumen method (known as the coefficient of utilisation method) devised by Harrison and Anderson provides only a convenient way of obtaining the average illumination on a horizontal plane. It gives no information on the variation of illumination at different points in an installation but to some extent does take care of inter-reflections.

Point by Point Calculation for Extended Linear Sources

A point by point method of calculating illumination from extended linear sources was developed by J. C. Lowson in 1949. The method correlates the illumination produced at a point on the working plane with the intensity emitted per unit length of lamp and reflector in a direction normal to the axis of the lamp.

It employs a simple formula (see Fig. 1) with only three terms, one of which, a factor F, is obtained directly from a special chart which automatically solves the difficult part of the equation. The necessary information can be obtained from the candlepower of the fitting in a plane normal to the major axis, and from the brightness distribution in planes containing the major axis. The horizontal illumination produced at point X on the working plane by a uniform parallel linear light source AB may be found by determining point O on the lamp such that angle AOX is a right angle, and then applying the formula given to each portion (OA and OB) of the lamp in turn. I is the candlepower per foot run emitted by the lamp in a direction parallel to OX, p the perpendicular distance in feet between the lamp and working plane, l the length in feet of the portion (OA or OB) of the lamp, and F a multiplying factor governed by the ratio $\frac{l}{p}$ and the angle α the angle of elevation of point O at X. Fig. 2 shows the family of curves from which the value of F can be read off the vertical scale opposite the point when the appropriate $\frac{l}{p}$ and α curves intersect. The family of



Lumens per Sq Ft at point $X = \frac{I}{p} F$

Fig. 1. Basic Formula.

* Miss Excell is with the Research Laboratory, B.T.H. Co., Ltd., Rugby. This article is based on a paper originally presented at an Informal Meeting of the I.E.S. in London.

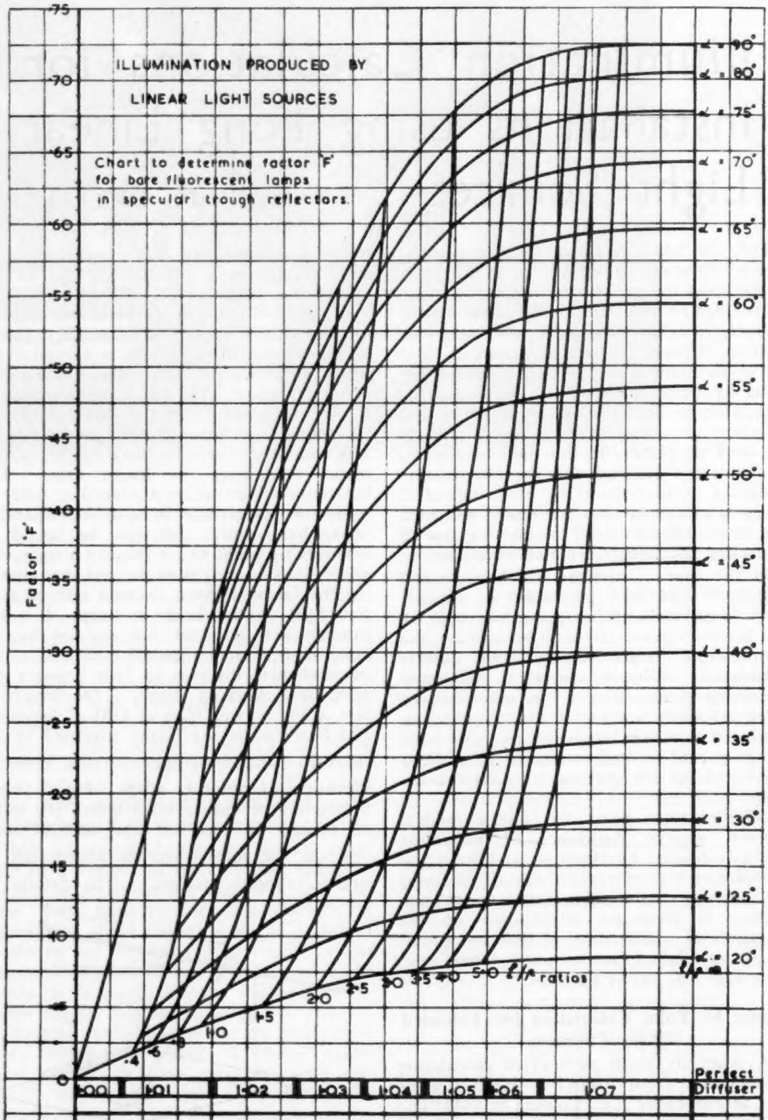


Fig. 2. Family of curves from which factor "F" is obtained.

curves has been drawn for a bare lamp and correction factors for use with a perfectly diffusing source (that is a source which does not suffer a reduction in brightness when viewed from directions close to its axis) are given. Suitable correction factors must be applied when the chart is used for lamps in fittings when, of course, their intensity distributions differ from those of bare lamps or perfect diffusers. One limitation to this method is that a direct application of it includes direct light only and excludes all inter-reflections from the walls, ceiling, etc.

Application of Method to an Installation

The application of this method of calculation to an actual installation and the method by which the inter-reflected light was determined will now be considered.

The building, 250 ft. long, 40 ft. wide, and 20 ft. high, is shown in the photograph (Fig. 3). The lighting consists of a direct lighting cornice employing fittings approximately 15 ft. in length and each containing nine 5-ft. 80-watt fluorescent lamps screened by a diffusing cover of fluted Perspex and arranged along the two side walls just below the ceiling level.

A polar curve of candlepower from a 4-ft. section of one of the fittings, in a direction normal to its major axis, was taken, with measurements of the relative brightness distribution of the fitting, in a number of planes at right angles to the plane in which the polar curve was taken. The candlepower emitted per foot run of the fitting was calculated from the intensity measurements, and the correction factors necessary for factor F obtained from the brightness readings.

This enabled, by a direct application of the method described previously, the illumination at any point on the working plane due to direct light only to be calculated. An extension of this method would enable the light distribution at points on the surfaces of walls, ceilings, etc., to be determined, from which their contribution to the total light could be estimated. With this installation, where the walls and ceilings are of such varying reflectances, such calculations would be very laborious.

To avoid these calculations, therefore, a scale model (one-fortieth full size) was made. The model, shown in Fig. 4, was constructed using two plywood end walls and four ½-in.-square wood strips 5 ft. long to form the main framework. The roof and side walls were made from white Bristol board and the ceiling panels and interior roof structure were made of white rigid P.V.C. To simulate the correct reflectances of walls and ceilings, which, in practice, include large areas of clear glass, cartridge paper was used on which appropriate areas were painted in neutral grey of the required reflection factor. The "value" of neutral grey required was determined by use of the Munsell colour system. Strips of opal Perspex were arranged along the outside of the model in appropriate positions, and illuminated by 5-ft. 80-watt fluorescent

Fig. 3. Photograph of completed installation showing arrangement and position of lighting fittings.

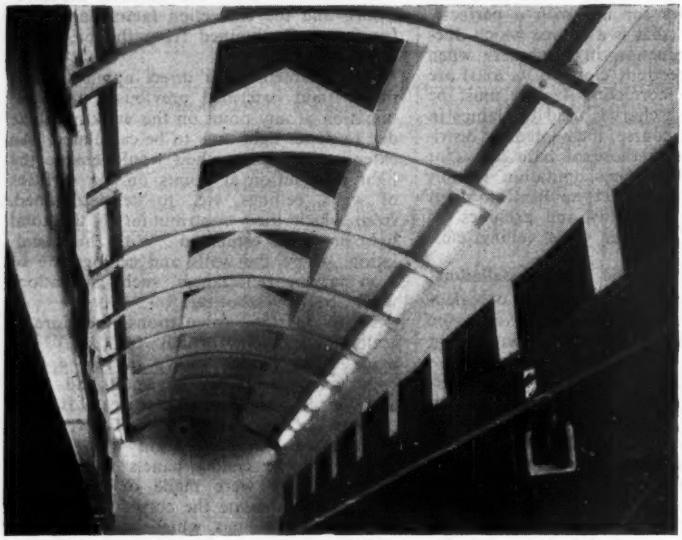


Fig. 4. Model of building used to determine inter-reflected light.

lamps, to give the flux distribution inside similar to that of the actual fitting.

Two sets of illumination readings were taken on the working plane of the model at positions corresponding to those for which the calculations were made. The first set was taken with the interior of the model completely covered with black card, and the second set with the correct wall and ceiling reflectances. From these results the ratio of the direct to the total illumination was found, from which the percentage added due to inter-reflections was determined.

By adding the inter-reflected illumination to the direct illumination, the total illumination at the various points on the working plane was obtained.

Illumination measurements taken on the completed installation were found to agree very closely with the calculated values (see Fig. 5).

Conclusions

We have found this point by point method of calculating illumination from extended linear sources a very satisfactory means of determining the direct illumination. The model technique is one which forms a convenient method of predicting illumination levels due to inter-reflected light in such installations.

I would like to thank Lever Brothers, Port Sunlight, Limited, for permission to publish the photograph of the building, and to thank Mr. L. J. Davies, Director of Research, the British Thomson-Houston Co., Ltd., for permission to publish this article.

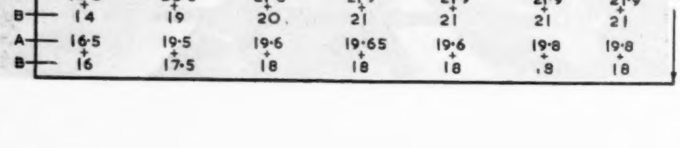


Fig. 5. Comparison of calculated and measured values.

An Investigation of Glare in Mine Lighting

During the past few years the lighting of coal mines has received considerable attention in this country. Freedom from glare is one of the chief contributing factors towards efficient lighting. The research described in this article was designed to provide a quantitative assessment of the parameters involved and to assist in placing mine-lighting design upon a firm basis.

By J. R. WAKEFIELD
B.Sc.(Eng.)

Review of Previous Work on Glare

The need for a comprehensive investigation into the phenomenon of glare arose at the beginning of the century following the introduction of incandescent gas and electric lamps for the purpose of street lighting. These light sources were small in area but of high brightness, and were at the same time dazzling and uncomfortable. Nutting(1) made the first useful contribution in 1920 by a preliminary study of glare from motor-car headlamps. He was followed by Bordon(2) in 1924 who carried out an analysis of the glare problem, but owing to insufficient data was unable to make further progress. A major contribution was made by Luckiesh and Holladay(3) who published a series of papers on this work. They assessed the disabling effect of a glare source by determining the brightness difference threshold under controlled conditions, initially without and finally with the light source in the field of view. By such means, Holladay showed that the brightness difference threshold increased directly with the illumination produced at the eye by the glare source, but was independent of its brightness. He introduced the term "equivalent veiling brightness" and demonstrated that the disabling effect of a glare source was similar to that of a veiling brightness over the field of view in that it increased the brightness difference threshold. His formula, derived from these observations, related the equivalent veiling brightness (B), with the illumination produced at the eye by the glare source (E), and the angle (θ) between the direction of this source and the line of sight:—

$$B = k\ E/\theta^2.$$

where k is a constant. He also concluded that the effects of individual sources were directly additive,

$$\text{i.e.}\quad B' = k'.\Sigma E/\theta^2.$$

These results and further work on discomfort glare enabled Holladay to confirm his hypothesis of the existence of an essential difference between the disabling and discomforting effects of glare, and it is felt that this successful recognition was one of his outstanding contributions. Using a "shock exposure" technique he showed that the degree of discomfort experienced by an observer was directly related to the intrinsic brightness of the momentary glare source. It follows, therefore, that two sources of equal candle-power, one of high brightness and small area, and the other of low brightness and large area, will produce similar disabling effects, whereas the smaller, by virtue of its higher brightness, will appear considerably less comfortable.

A study of the disabling effects of a glare source was carried out in more detail by Stiles(4). He laid particular emphasis on street lighting conditions and succeeded in

This article is based on a paper originally presented at an informal meeting of the I.E.S. in London.

confirming Holladay's findings. It was later demonstrated by Lythgoe[5] in 1936 that the presence of a glare source in the visual field did not always give rise to reduced acuity, and in certain circumstances an improvement may take place. The reason for this is that it is possible for a bright source in the field of view to cause a temporary contraction of the pupil and thereby extend the resolving power of the eye. The extent to which the receptor mechanism responds to this effect and the ultimate visual ability resulting from the two opposing factors, requires further investigation. A useful conclusion emerged from Lythgoe's study when he showed that if the general illumination level was low, a major improvement in visual conditions could be effected by an increase in illumination, whereas at higher levels a similar improvement could be brought about more expediently by increasing the apparent size of detail. A binocular method of appraisal was contrived by Schouten[6] in determining the apparent decrease in brightness of an illuminated field when a glare source was placed within the line of regard. The test field was compared with a standard surface of variable brightness, and a brightness-match was obtained with and without glare. His resulting formula is very similar in form to those of Holladay and Stiles, and further confirms that disability effects are independent of source brightness. Of particular interest in the present study is his discovery that the time of recovery from glare is directly dependent upon the time of previous exposure.

It is still uncertain whether sources of various colours and spectral composition provide relatively different disability and discomfort effects. The investigations by Luckiesh and Moss[7], Stiles[8], Boumat[9], and Ivanoff[10] appear contradictory, but it is almost certain that radiations from the middle and red end of the spectrum are less glaring than white and blue lights.

Specific studies of discomfort glare have only comparatively recently been made, and consequently have not received the detailed treatment of the disabling effect investigations. It has been suggested that the widespread use of the "non cut-off" system of street lighting in this country, where direct light is allowed to enter the observer's eyes, initiated researches into comfortable vision. Hopkinson[11] in 1940 employed a unique method of appraising the factors which cause discomfort, and presented his findings in a form that was of immediate use to street lighting engineers. This work, using the same technique, has been extended by Petherbridge and Hopkinson[12] to lighting in buildings, their paper providing one of the most detailed and thorough investigations to date.

Other investigations carried out in Holland and the United States have provided remarkable agreement with those of this country. Luckiesh and Guth[13] and Guth[14] used the "momentary exposure" technique in which the observer was presented with the glare source in a series of one-second-interval flashes. This method tended to indicate a greater sensitivity to discomfort glare, but it has been shown that the differences between their glare-formula and the British formula is "less than the significant differences in glare assessment made by different observers, over the range of the experiment." This was concluded from data derived from an experimental check made on the different techniques. The Dutch investigators, Vermeulen and de Boer, obtained results which agreed very closely with those of Petherbridge and Hopkinson.

A summary of the discomfort glare formulae obtained for the central range of brightnesses is given in the expression

$$\text{Glare Constant} = \frac{(B_s)^n (W)^m}{(B_b)^k}$$

where B_s = source brightness.
B_b = surround brightness.
W = solid angle subtended by source at observer's eye.

Investigation	n.	k.	m.
Holladay (1926)	3.3	1.0	0.83
*Hopkinson (1940)	1.3	1.0	0.3
Harrison (1944)	3.3	1.0	1.7
Vermeulen and de Boer (1948)	1.7	1.0	0.5
Luckiesh and Guth (1949)	2.3	1.0	0.84
Petherbridge and Hopkinson (1950)	1.6	1.0	0.8

* These results were obtained in a street lighting study, where much lower brightnesses were applicable, and the discrepancy suggests that it is not reasonable to include them in the comparison.

An American contribution by Putnam and Faucett[15] has also extended the range of discomfort glare investigation to the lower brightness levels. A modified form of Guth's apparatus and the "intermittent exposure technique" were used. They re-

ported that for the smaller source sizes, the slopes of the B_s/B_b logarithmic curves were less, thus indicating that for lower surround brightnesses and source sizes, the previously determined curves cannot be extrapolated with validity. In other words, the linear relationships do not persist, and it is impossible to apply a single empirical equation to the complete range of environmental conditions. This was also predicted in the paper by Petherbridge and Hopkinson, who further emphasised that their findings applied strictly to the central linear portion of the equal glare characteristics.

From a study of the foregoing it became apparent that if any useful work on glare in mine lighting was to be carried out, it would be necessary to make an investigation of the factors governing disability and discomfort glare at the surround brightnesses encountered in underground lighting.

Special Problems in Mine Lighting

It has always been necessary for the miner to rely entirely upon artificial light, both to enable him to reach his place of work in the pit, and to carry out his regular tasks with safety and efficiency. Ideally, a satisfactory underground lighting system should contain adequate general lighting supplemented by individual hand or cap lamps, and it is towards this end that present trends are progressing. Even so there can be no comparison between the conditions under which the present-day miner works and those in factories, where much higher levels of illumination are provided.

In general, mains installation lighting problems, depending upon their location, fall into two main groups, namely, roadways and the coal face. Common to both are the low reflection factors of coal and other loose material. The majority of roadway installations consist of 60- or 100-watt tungsten lamps in fittings suspended along the centre of the roadway at 20 to 40 ft. spacing. Electric mains lighting is permitted by the regulations to within 50 yd. of the coal face along the intake, and within 300 yd. along the return shaft. At the coal face itself exceedingly restricted mounting heights are usually available, coal-seams of 24 in. are not uncommon, and great difficulty is experienced in providing a reasonably uniform level of illumination along the working plane. The reflection factor of coal varies from between 3 to 12 per cent., and on an experimental face it has been reported that with 40-watt 2-ft. fluorescent lamps, at a distance of 9 ft. from the face, the average illumination opposite the lamps was 0.68 lm./ft.^{2} and at points midway between the lamps 0.38 lm./ft.^{2}. A value of 0.4 lm./ft.^{2} has been accepted as the minimum standard for face lighting[16], this providing sufficient margin for the avoidance of scotopic vision. It is worthy of note that a typical cap lamp,

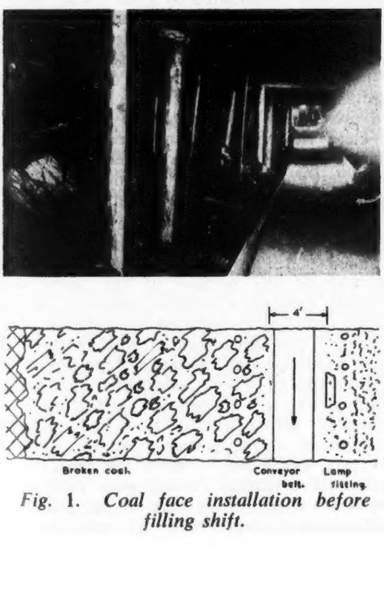


Fig. 1. *Coal face installation before filling shift.*

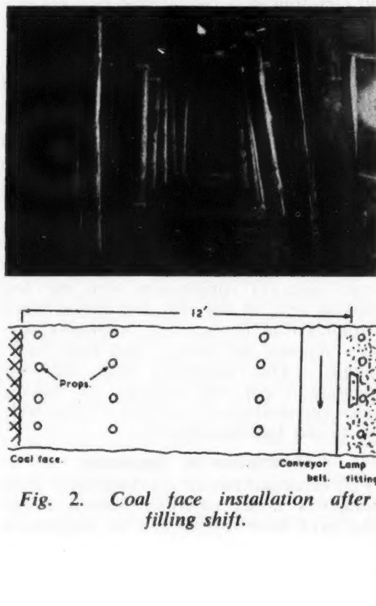


Fig. 2. *Coal face installation after filling shift.*

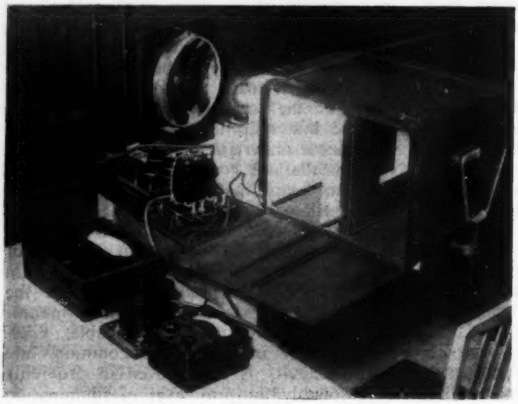


Fig. 3. Apparatus used in the investigation.

when used alone with no general lighting, provides just this figure over an area of 9 sq. ft. at a throw of 36 in. The precise distance of the face from general lighting fittings may vary from 6 ft. at the beginning to 12 ft. at the end of a shift, and, in addition, the whole installation has to be uncoupled and moved forward each day. The installation also has to withstand the hazards of flying debris following the use of explosives, and must conform to exacting flameproof requirements. A plan and elevation of a typical coal-face installation along a 4-ft. seam is shown in Figs. 1 and 2. In Fig. 1 the coal has been undercut and blasted down in readiness for loading on to the conveyor. At the end of this shift the face is left in the condition shown in Fig. 2, when it is at its maximum distance from the fittings. The fittings used in this particular scheme contained twin 15-watt 18-in. fluorescent lamps and were mounted at 15 ft. spacing.

Unfortunately in coal mines, as far as disability and discomfort glare are concerned, the conditions could hardly be worse, since in conjunction with the low adaption state of the eyes, the almost black surrounds lead to excessive brightness contrasts between the sources and their backgrounds. This combines with the low mounting height and diversity of viewing angles and distances to present a formidable task to the lighting engineer.

Description of Apparatus

Full investigations of the discomfort glare parameters under carefully defined conditions have been carried out by Hopkinson and his co-workers for background brightness levels and source sizes appropriate to both street lighting and to lighting in buildings. Using a form of their apparatus some preliminary observations have been completed and similar relationships have been obtained over the lower brightness ranges. The apparatus shown in Fig. 3 consisted of an internally blackened wooden box, fitted with a viewing window at one end and slots to accommodate a card at the other. This card, coated with matt-white titanium oxide paint, was illuminated by four 3-watt lamps mounted on the whitened surface of a screen contained in the box. Light from the lamps was diffused by a further screen of 040 "Perspex" placed in front of them, and rectangular apertures were cut in the screens to present an observer at the window with a clear view of the illuminated white card. The observer's eyes were located by a rubber chin rest and a forehead pad mounted below and above the window respectively.

A 60-watt lamp and spherical mirror combination was arranged to flash the 8-in. condenser to a required brightness, and a portion of the surface of the latter was viewed through a circular aperture in the white card and constituted the variable glare source. The dimension of this aperture at the fixed viewing distance represented a source-size of 0.0011 steradians, this being equivalent to a typical refracting-glass tungsten fitting at 10 ft. The angular separation of the source from the line of fixation was 5 deg. Both the source and surround brightness lamps were controlled by fine Variacs on the high voltage side, and measurements were made by voltmeters in

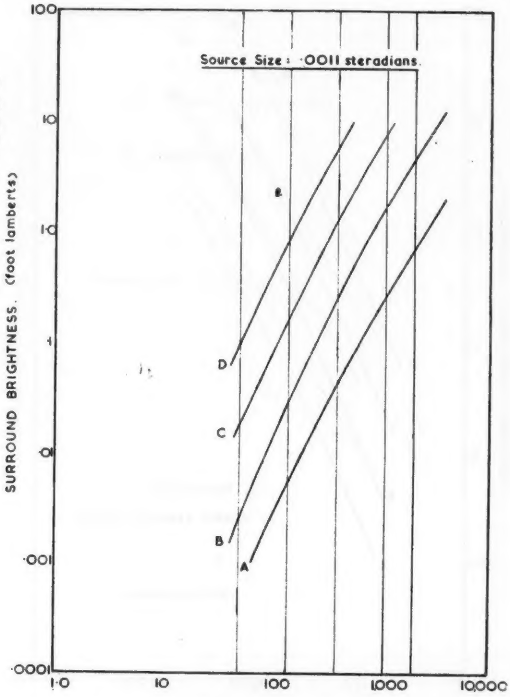


Fig. 4. Equal-glare curves relating the brightness of a glare source with that of its surroundings for four degrees of discomfort :—

A—just intolerable.
B—just uncomfortable.
C—just acceptable.
D—just imperceptible.

Size of source—0.0011 *steradians.*

permanent connection across each lamp.

Preliminary tests were made to determine the optimum lamp wattages to provide the required brightness ranges without serious colour difference. To further this end the upper hemispheres of the four surround brightness lamps were coated with white diffusing paint, and the "Perspex" screens were made interchangeable with others of more or less dense material. The source optical system was adjusted, and a correction applied for the two eye-viewing positions. Calibration was carried out at five levels of source brightness, and a chart was constructed relating surround brightnesses and surround voltmeter readings. A Holophane Lumeter was used for all brightness measurements, this being previously calibrated against a standard lamp and reflection surface.

Experimental Technique

An experimental technique involving the "multiple criterion" principle was used, the observers being asked to make adjustments to the surround brightness to give four degrees of discomfort glare (just intolerable, just uncomfortable, just acceptable, and just imperceptible) at the five levels of source brightness. A considerable period of dark adaption was allowed (15 to 20 minutes), and the observers were presented with the lowest source brightness first. They then made the necessary adjustments to the background brightness by means of the Variac, until they had obtained each of the four criteria in turn. Corresponding readings of the surround brightness voltmeter were noted at each step. Eight observers, all inexperienced, were employed. They were all given sufficient practice, and were familiarised with the apparatus and technique before commencing the study. Reproductions of the criteria chart were pinned up in as many places as possible, and it was also on view during the observations. No time limit was imposed within which to complete a set of observations, and it should be added that, although the observers were not

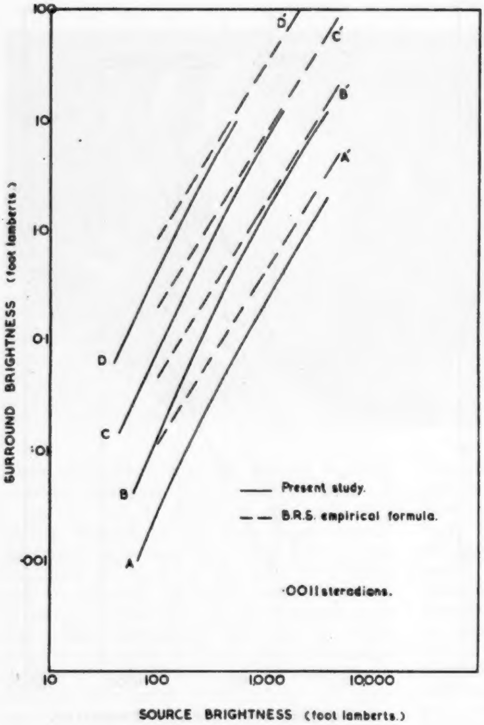


Fig. 5. Comparison of equal-glare curves obtained in present study with the Petherbridge-Hopkinson empirical formula.

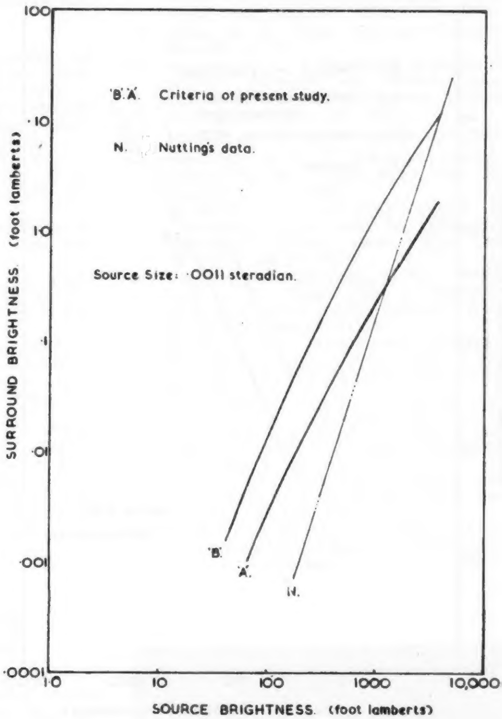
used to making settings of this nature, they were all accustomed to making careful scientific adjustments.

Comparison of the Results with Previous Work

Equal-glare curves relating the surround brightness required to maintain the four criteria of discomfort glare within a range of 50 to 2,000 ft.-lamberts source brightness are shown in Fig. 4. They are averaged smooth curves derived from the observations of the eight subjects. It is possible to compare these curves directly with relationships calculated for the same source size from the Petherbridge-Hopkinson empirical formula. It will be seen in Fig. 5 that at the lower levels to which they extend, the full-line curves are of greater slope, and hence a greater application of surround brightness was necessary to maintain the same degree of discomfort glare. At the same time the level of surround brightness is less than that required by Petherbridge and Hopkinson's team of observers. This may be due to a slight difference in the interpretation of the criteria, and also more probably to the relative inexperience of the subjects. It has been shown by Hopkinson(17) that inexperienced observers become more sensitive to discomfort glare as experience in making the assessments is gained. However, the trend of the curves is quite definite, and they are in fairly good agreement with the previous investigation.

Further comparisons with other work are shown in Fig. 6 (Nutting) and Fig. 7 (Holladay, Luckiesh and Guth, Putnam and Faucett). Nutting was interested in the limiting conditions of glare from automobile headlamps, and consequently set his criterion at a higher level of the borderline between tolerance and intolerance. Luckiesh and Holladay used a method similar to Nutting's involving steady fixation, where an element of time was introduced to allow the adaption state to change towards the glare source brightness. The other investigators subjected their observers to intermittent exposures of the glare source, and deter-

Fig. 6. Comparison of the "just intolerable" and "just uncomfortable" criteria with an extrapolation of Nutting's data.



mined the borderline between comfort and discomfort (BCD). The most relevant comparison is that with Putnam and Faucett's results, since both studies were designed for similar brightness ranges. It appears that their "BCD" criterion falls somewhere between the "C" and "B" criteria of the present study. The curves are almost parallel at their lower ends but beyond approximately 100 ft.-lamberts source brightness, this no longer holds, and at 1,800 ft.-lamberts the "BCD" crosses the "just acceptable" criterion. In general the mean slope of the four present criteria is less, and this may again be due to the difference in technique. Unfortunately any further comparison is handicapped by the variation in the nature of the selected criteria.

Interpretation of the Results

Whilst it is undesirable to make assertions based on a piece of incomplete research, it is felt that this particular study provides at least a qualitative measure of the factors involved. It follows directly from the mean spacing of the equal glare curves that at any given source brightness, a decrease in discomfort glare through one criterion may be effected by raising the surround brightness of the fitting by 0.74 log. ft.-lamberts, i.e. by a factor of 5.5. It also follows that it is essential that the surface brightness of a mine-lighting fitting should be kept as low as possible, and that when installed, the corresponding brightness of the surroundings should remain comparatively high. The factor of 5.5 appears very considerable when weighted with the common 3-12 per cent. reflection factors of normal background surfaces. This suggests that, in addition to generous application of whitewash and dusting, mine-lighting fittings should be designed to transmit a much higher proportion of light on to their immediate surrounds than is customary in practice. Until very recently there have been no fittings available that were designed for the specialised task of lighting in coal mines. In almost all cases heavy industrial multipurpose types supplied with flameproofing

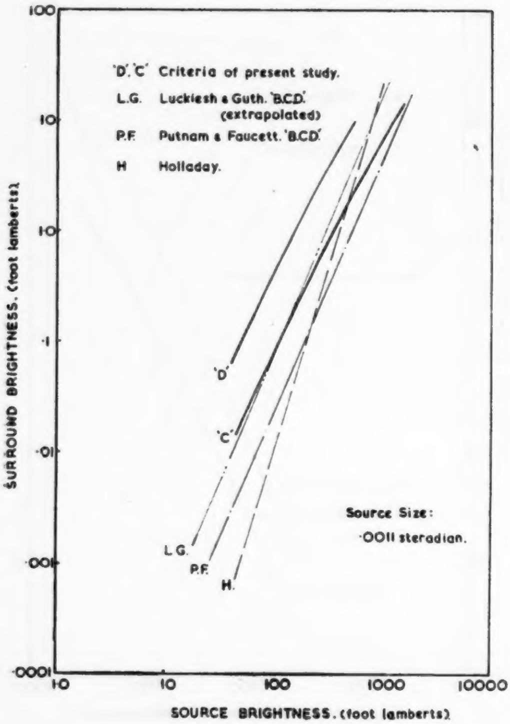


Fig. 7. Comparison of the "just acceptable" and "just imperceptible" criteria of the present study with results obtained in the United States—Holladay's formula and the B.C.D. criterion of Luckiesh and Guth and Putnam and Faucett.

flanges and terminal boxes have been pressed into service, often with unsatisfactory results. Several attempts have been made to use fluorescent lamps for lighting the coal face, but in some instances the advantages of the comparatively low surface brightness have been considerably reduced by enclosing the lamps in fittings that cut off light to the immediate surrounds. It is possible, from the equal glare curves, to determine the limiting brightness of a fitting for any particular background brightness in order to provide comfortable vision.

Further work is being carried out on the effect of the size, colour and shape of sources and their position in the field of view. A further study, designed to test whether the sensitivity of a workman to glare is affected by extremes of temperature and humidity is in preparation. It has become apparent that over recent years research workers have grown more conscious of the need to present results and conclusions in a form that can be readily applied without intermediate translation by the engineers and technicians confronted with the initial problems. This naturally leads to a considerable degree of specialisation, but it is to be expected that, at some future date, when the picture is complete, the many researches on a subject, such as glare, will be gathered together and presented in an all-embracing Code of Practice. The author hopes that from the findings of this present study it will be possible to offer some useful recommendations in the field of mine lighting.

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Industrial Lighting

(*Continued from page* 340)

sodium resistant inner layer. It is operated in a detachable vacuum jacket which retains the heat from the discharge and thus ensures that the necessary sodium vapour pressure is attained.

The nominal life for all ratings is 3,000 hours, and the same vacuum jacket may be used with two or three successive lamps. The average throughout life efficiencies lie between 64 lm./w. for the 140-watt rating and 49 lm./w. for the 45-watt rating.

For certain industrial purposes, notably the open area lighting of stock yards or sidings, the sodium lamp is eminently suitable. In such places colour rendering is usually of little importance and is quite secondary to the basic requirement of a light source of high efficiency.

(vi) Tungsten Lamps

Little more can be added to the earlier comments on tungsten lamps but, briefly, the advantages of these lamps lie in their low capital cost, simplicity of operation and good colour rendering. As has been mentioned previously, however, the new types of discharge lamp and fluorescent tube are rapidly becoming the major contributors to industrial lighting practice.

Lighting Trends in the U.S.A.

A report on a recent lecture to the I.E.S. given by Dr. Ward Harrison, President of the International Commission on Illumination.

Dr. Harrison began his lecture by saying how glad he was to have the opportunity to speak to members of the I.E.S. of Great Britain and extended to the Society greetings from the I.E.S. of the United States and from the officers of the International Commission on Illumination. With regard to the C.I.E. he said that there were now some 20 member countries, and he briefly dealt with some aspects of the work of the Commission, mentioning that arrangements were now being made for the next meeting of the Commission in Switzerland in 1955.

Turning to lighting trends in the United States, Dr. Harrison said that more than half the general lighting was by fluorescent lamps and that new installations were almost entirely fluorescent. He mentioned the range of colours available, but said that all the manufacturers are working towards a uniform colour, though there are still differences between manufacturers—and sometimes, it is rumoured, differences between lamps from the same manufacturer.

The next trend that was noteworthy was lamps operating without the use of starters. In England conditions were in one way favourable for fluorescent lighting because of the 220-volt supply, just as there was some disadvantage with incandescent lamps due to the lower efficiency of those made for the high voltage. Generally speaking, in America with lamps greater than two feet in length a step-up transformer has to be used, since the prevailing voltage is 120. So long as a transformer is necessary, many people prefer to run the voltage up to 450 and start a 4-ft. 40-watt lamp immediately. Instant starting is obtained that way, and starters are eliminated. Of course, on the other hand, the ballasts are bigger and heavier and more expensive.

Except for initial expense about the only sacrifice involved in instant start is the fact that you do not obtain as good correction for stroboscopic effect; the lead and lag lamps are not 90 deg. out of phase, but more nearly 165 deg. out of phase. On the other hand in America flicker is not as conspicuous as the standard supply is 60 cycles as against 50 in Britain. Dr. Hopkinson has found that there is a substantial difference between 50 and 60 cycles in this respect. A number of special circuits have been devised, some putting the lamps in series after starting to avoid having to supply 450 volts for each lamp.

Eight-ft. lamps are coming into substantial popularity. In the early stages of fluorescent lighting there was considerable competition in America between hot cathode and cold cathode lamps; the cold cathode people had a less efficient lamp because of the losses in the electrodes, and they asked their engineers of what length they would have to make a fluorescent cold cathode lamp to be as efficient as a 4-ft. hot cathode; the answer was eight feet, and they standardised on that. Then the hot cathode people made an 8-ft. lamp, too, and called it slimline.

A feature of slimline lamps is that they have one central pin which permits the use of a push-pull socket which is generally preferred to the older types. Another reason for the popularity of long lamps is that as the length increases the starting voltage does not increase proportionately; if a 4-ft. lamp starts at 450 volts, an 8-ft. lamp will start at 650 volts.

Dr. Harrison said he would like to take a few minutes to discuss a subject which is quite dear to him, namely the progress which is being made in the evaluation of glare. Glare must be regarded as the enemy of adequate lighting; it is easy to design a

lighting system that will cause no unfavourable comment at a level of illumination of 5 ft.c. and it is still easy at 10 ft.c., but at 50, 75 and 100 ft.c. if you do not use skill you will get a result that people do not like. The one thing that limits the foot-candles that a man employs in an office or drawing room or schoolroom should be his purse. However, with incandescent lighting to-day, it is the heat from the lamps which puts a limit on foot-candles, and with fluorescent it is the feeling that there is too much light, or, more correctly, too much glare.

There are two principal sources of information and data on glare evaluation: one is at Nela Park, Cleveland, and the other at the Building Research Station at Watford. These laboratories are coming closer and closer together in their findings and, because of this progress, as foot-candle levels increase in England—and Dr. Harrison said he was sure that they will—it will be easier to avoid glaring installations than it was at first in America.

Some five years ago, he said, he had discussed this subject at Harrogate. The point he had emphasised then was that it is not only the brightness of a light source that is important, and not only its contrast with the surroundings, but also the total area of the light sources to which the eye is exposed. As illumination levels increase source area becomes relatively more and more important until it finally assumes a position where it has greater effect upon your comfort than even the contrast between the light source and its surroundings. The purpose of the glare factor tables is to predetermine whether or not an installation will be comfortable. And at that point, he said, you might say "comfortable for whom?" There is a wide diversity of opinion between individuals on this point, and particularly people who are inexperienced are likely to be more lenient in their judgments than those who are experienced. You might conclude from that that people who are inexperienced do not suffer from glare as much as the experts, but those same people, after they have lived in a room for some time, will frequently tell you that "there is too much light in the room," and that they are happier when half the lights are out. It is not really that there is too much light—they think that is the trouble, but the truth is that the light sources are too large in area or too bright and, although the inexperienced may be lenient in their judgment when looking at the lighting, they are just as critical as anyone else when it comes to living with it; that is what the expert can foresee.

Dr. Harrison then showed some slides of installations in the United States. Commenting on the three or four industrial interiors which he showed he said that the aim was to provide in factories lighting of as good a quality as that provided in offices. He pointed out that it was becoming realised in America that it was decidedly uneconomical to allow a man to operate a machine costing many thousands of dollars under poor lighting conditions. Why not treat him as well as a stenographer with a 200-dollar machine?

He showed one slide of a large industrial installation in which 750-watt internally silvered lamps were used; these lamps, he said, were very useful in relatively inaccessible locations because they need almost no cleaning. In connection with office lighting he mentioned the populartiy of the corrugated plastic ceiling. He also showed some examples of domestic lighting and said that it was desirable to light the walls either by fluorescent lamps concealed behind valances or by table or standard lamps which allow the light to spread horizontally and on to the walls. By this means a large component of horizontal light was obtained which was found much more flattering to people than light coming straight downward from the ceiling. In food stores much use is made of fluorescent lamps supplemented with tungsten spot lights.

On the question of fluorescent street lighting he said that Great Britain was undoubtedly leading America. There were, however, reasons why fluorescent street lighting had not become so extensively used in the States, mainly because economic conditions were quite different; the cost of electricity was relatively low and the cost of labour was very high, so that fluorescent street lighting installations were, in many cases, more expensive to install and operate. On the other hand, there is a great and growing interest in fluorescent lighting at the present time.

Dr. Harrison gave his impressions of the Coronation, which he regarded as magnificent and inspiring throughout; he observed that the people of the Commonwealth were indeed fortunate that in the Sovereign they had a head of State who is looked upon with respect and affection by all—a situation which does not always exist in other countries.

As a final comment on lighting, he said, "I have not yet seen any outdoor decorative lighting comparable with that now in the

Mall in London, and again I have not yet seen any indoor illumination to equal the lighting of Westminster Abbey for the Coronation. In that problem there were three prime requirements, distinctly individual, and almost mutually exclusive. For the first time lighting designed to make television and colour motion picture photography possible was likewise the most effective that could have been devised for viewing the great spectacle by those people seated in the Abbey; for people at great distances from the crowning it was just as necessary to have 120 ft.c. there as it is on the stage of a theatre, and yet it was provided in a way that was infinitely more kind to the principals who took part and who continued under it for some three hours. For that installation, and for the genius of those who made it possible, my admiration is unbounded."

The discussion following Dr. Harrison's lecture was opened by Mr. H. G. Campbell, who had recently returned from the United States, who said how much the audience had enjoyed the lecture. He said he wished that Dr. Harrison had stressed a little more the very conscious feeling that there is among lighting engineers in the States for low brightness and comfort. He also asked if much use was made of blended light, particularly for high-bay lighting, and asked Dr. Harrison to clarify the difference between the American "Rapid" start and the British "Instant" start.

In reply to Mr. Campbell, Dr. Harrison said that there was a greater stress on comfort in America than there is here, but said that it was surely something lighting engineers in Britain will have to consider in due course.

With regard to high-bay lighting, he said that pairs of lamps, 400-watt mercury and 500- or 750-watt incandescent, in adjacent fixtures are usual. Also available for similar applications was the mercury lamp with a fluorescent coating on the outer bulb.

On the rapid start the difference between it and the instant start is that with instant start the cathodes are stone cold when the arc has to jump between them. With rapid start, due to the design of the ballast, a very brief but rather effective heating of the cathode is obtained and under these conditions the arc starts at a lower total voltage, about 280 volts. At the present time there is a saving of about 15 per cent. in the cost of the ballast and the circuit is a little more efficient and also more complicated. An objection is that we already have a switch starting lamp with its regular cathode, we have instant start with its special cathode and the rapid start needs a still different cathode. It is hoped that the rapid start lamp will be made so that it can be used with the old switch starting circuit also. Then because of its higher efficiency it should take the place of instant start in the new installations and in five years there may be one lamp—rapid start.

Mr. A. G. Penny asked to what extent de luxe colours of fluorescent tubes were becoming popular in the States. Dr. Harrison said that these lamps formed a very small percentage of the total number of fluorescent lamps in use. He thought, however, that the de luxe colour lamp was the only lamp which will make fluorescent lighting acceptable to women in the home. There was some prejudice against the use of fluorescent lighting in the home because people have had experience of lamps which made one look unwell, but he thought that in time the de luxe colours would overcome this prejudice.

Mr. D. C. Pritchard asked if the levels of illumination used in practice in the United States were as high as those recommended.

In the newer installations, said Dr. Harrison, the levels are surprisingly high. Some of the power supply undertakings were at first worried that the introduction of fluorescent lighting might cut down the consumption of electricity. The consumption of electricity for lighting, however, had increased more rapidly than it had before the introduction of fluorescent lighting, and since the average fluorescent lamp is three times as efficient as incandescent lamps, it means that foot-candle values are on the average at least three times higher than they were with incandescent. In comparing levels of illumination in the two countries one must remember the difference in economics; cost of electricity is relatively lower and wages higher in the United States, so that higher levels of illumination are economical. During the war munitions plants were built with Government money and the very best lighting was put in. When the war was over the industrialists who had operated the Government projects went back into their own plants and insisted on 50-ft.c. installations such as they had become accustomed to. This, said Dr. Harrison, was pretty good proof that these high illuminations were worth while.

Mr. Anderson said that the most commonly used fluorescent lamp in the United States was the 4-ft. 40-watt lamp, whereas in this country the "bread and butter" lamp

(Continued on page 363)

Light, Colour and the Eye

By N. H. AITKEN

This short article sets out to deal as simply as possible with some of the phenomena observed when coloured objects are viewed under coloured light sources and against coloured backgrounds. This leads to an explanation for the need of right choice in fluorescent lamp colour for a particular application.

As the title of the article suggests it will deal with the subject of colour from a purely qualitative point of view, and there is no intention that this paper should be regarded as anything more than a simple explanation of some of the subjective qualities of light and colour.

Coloured Filters and Coloured Surfaces

It is a well-known fact that the appearance of a light source can be altered by placing a filter between it and the observer, the alteration depending on the filter's transmission curve. For instance, if the source has a continuous spectram (e.g. an incandescent lamp) then it will appear blue if a filter whose transmission curve is that shown as A in Fig. 1. is placed before it. If now this filter is placed between the same light source and a white surface, the latter will appear blue.

If the white surface is illuminated directly by the source, but viewed through a filter,

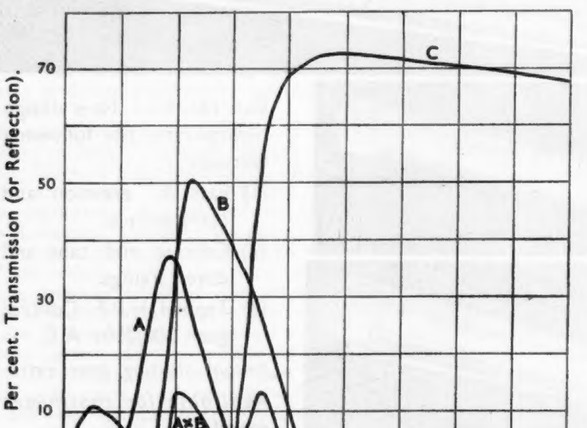
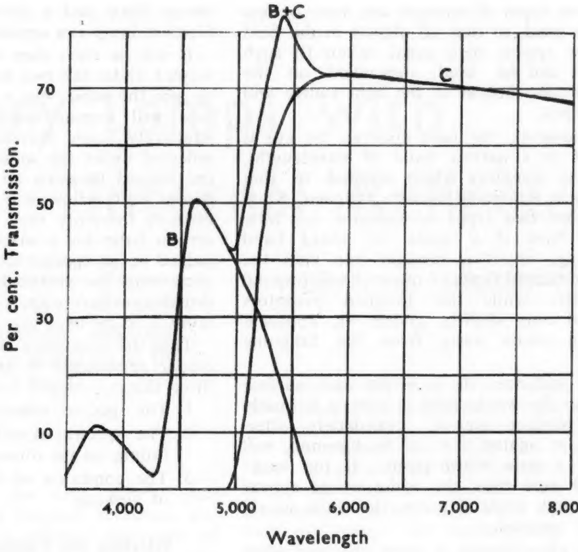


Fig. 1.

Fig. 2.



it will have exactly the same blue appearance as before.

Now suppose a coloured surface is viewed directly under the same continuous waveband source and that it has a spectral reflection curve as shown by (B) in Fig. 1. The surface appears blue-green. When the blue filter is placed between the source and the coloured surface, the latter will once again appear blue, as only blue light reaches it. The appearance will not be quite the same as in the previous case, for the spectral reflection curves of the two surfaces at the blue end of the spectrum are not identical. The appearance will not change, however, if the blue-green surface is viewed through the blue filter instead of having blue lights shone upon it.

If a yellow filter which transmits a small amount of green light is used, the surface will appear a dull greenish yellow, for only a small amount of this particular wavelength reaches the eye. Suppose now a blue-green filter, a yellow filter, and a white surface are used. Using the yellow filter between the source and the surface, the surface appears yellow, if it is now viewed through the blue-green filter it will appear greenish-yellow, for only that waveband reaches the eye. The effect would be exactly the same if the two filters were swapped over, or both placed on the same side of the surface. In other words, the order in which the interference takes place has no effect on the ultimate result.

All these examples have been of subtractive colour mixing.

If, however, two continuous spectrum sources are used, one with the blue-green filter and one with the yellow filter, and arranged to throw their light on to the white surface, the latter will appear white, as all the wavebands of light are falling on the screen to be reflected as shown in Fig. 2. This is an example of additive colour mixing.

This latter phenomenon is used practically in blended light units, where the bluish light of the mercury vapour lamp is mixed with the yellowish light of the tungsten filament lamp to give a fairly satisfactory colour rendering white light.

Colour and the Eye

It is not proposed to discuss here the various theories on how the eye resolves a picture on the retina into a coloured image in the brain. It is going to be assumed that the cones, the nerve endings in the retina used for colour vision, are made up of three different types of receptors which respond to blue, green, and red stimuli, respectively.

Under most circumstances the eye views surfaces with many different spectral reflection distributions under a white light, and

the three types of receptor are more or less equally used, so that all objects in the field of view appear their usual colour (if such a term can be used), dependent on the spectral distribution of the light source and the object.

If, however, the light entering the eye is limited to a narrow band of wavelengths, then the receptors which respond to that particular waveband become fatigued, while the other two types of receptor are little used. Now if a white, or broad band reflecting, object is brought into view the two unfatigued types of receptor will respond normally, while the fatigued receptors respond only slightly, giving an apparent shift in colour away from the fatiguing colour.

For instance, if a bright red surface occupies the whole field of view, a normally white surface viewed immediately afterwards, or against the red background, will appear a pale bluish-green. If the background were blue, the white would appear orangy-red, while if green, the white would appear purplish.

This phenomenon is often observed when driving or walking. If one passes from a stretch of road lit by sodium lamps to a tungsten filament installation, everything appears to take on a bluish tinge. Similarly, when moving into a tungsten-lit area from a high-pressure mercury installation, everything takes on a yellowish appearance.

This effect wears off in a fairly short time, as the fatigued receptors gradually recover and respond equally with the others. In a case where a bright, small waveband background is maintained, then the receptors cannot recover, but the brain or eye adapts itself somewhat and colours tend to return to their normal colour, though there is still considerable colour distortion.

Colour Rendering

It is possible for light sources and surfaces to have the same colour appearance, while their spectral distribution curves are quite different, for the eye, unlike the ear, cannot resolve waves falling upon it into their individual bands.

Thus a white appearance is given when the three types of receptor are stimulated in certain ratios and it is immaterial to the brain whether these stimuli are the result of monochromatic (single wavelength) red, green, and blue light, or a continuous spectrum; this fact applies to any colour. For instance, the colour from a sodium discharge lamp and a yellow filtered tungsten filament lamp can appear almost identical.

It will be clear then that a white surface viewed under the two sources appears more or less the same, but a multi-coloured surface will appear quite different, as only effectively single waveband yellow can be reflected under the sodium lamp, but under the filtered tungsten all colours can be reflected, but yellow will predominate. It is obvious therefore that the usefulness of a certain lamp for a particular job cannot be judged on its appearance alone—the appearance must be correlated with its spectral distribution before the situation in which the lamp is to be used can be determined.

Thus the conclusion can be drawn that the colour appearance of an object depends on three things:—

1. The spectral reflection of the object.
2. The spectral distribution of the light falling on the object.
3. The condition of the eye at the time of viewing.

Selecting the Correct Light Source

For general lighting purposes where colour discrimination is not important, the eye adapts itself without much objection to colour rendering given by almost any illuminant with the very important exceptions that it will not accept the appearances of foodstuffs and the human complexion unless they approach those obtained under average daylight or a continuous spectrum artificial light, weighted towards the red end of the spectrum. The reasons for this are probably mainly psychological.

It is preferable therefore to use the warmer colours of fluorescent lamps in areas devoted to social activities; unfortunately, owing to the eye's response to the various wavelengths, these must necessarily be of lower efficiency than the colder colour lamps.

The colder lamps are used where the criterion is high illumination rather than pleasant colour rendering, for colour discrimination with these lamps is quite good in comparison with that under, say, high-pressure mercury vapour lamps.

Where good colour discrimination is required, as in colour matching, special lamps or units have to be used.

The picture on page 334 is of Willerbys' new Southampton shop. The architects were Messrs. C. J. Epril and Associates, and the lighting is by Courtney Pope (Electrical), Ltd.

Mercury Lamps with Internal Reflectors

The following article discusses the economic value of M.V. lamps with internal reflectors such as are now available in the United States.

By A. G. BROWN.*

In this country the only widely used lamps incorporating internal reflectors are the tungsten filament reflector spotlights of the well-known 150-watt type and the recently introduced 75-watt rating, and the infra red reflectors used for heating purposes. In the United States, however, mercury discharge lamps incorporating internal reflectors have been developed and are being used for industrial lighting purposes in place of the more conventional type of lamp and rather costly fitting. Due to the shape of the discharge inner careful design of the reflector bulb would be necessary to obtain the light distribution required for general lighting purposes and in installations careful siting of the lamps would be necessary to avoid glare.

The use of mercury reflector lamps has the following advantages:—

(1) A considerably lower initial installation cost due to the use of a simple protective cover over the lamps instead of an expensive fitting which may contain elaborate optical control equipment.

(2) A lower maintenance cost as far as cleaning is concerned. The drop in light output of a lighting unit due to the accumulation of dirt on both the fitting and lamp surfaces is an important factor and in industrial areas the cleaning of lamps and fittings may become necessary at frequent intervals thus incurring the user in a substantial annual cost. Lamps with internal reflectors would have a very much better lumen maintenance by virtue of the internal reflector and the small amount of dirt that can accumulate on the bulb face when the lamp is operated in the cap up position. When the lamp is in operation the natural air currents around the lamp would also help to prevent dirt accumulating on the bulb face.

When considering whether a new type of lamp would be a practicable proposition from an economic point of view there are two methods of approach; one is to decide, on a works basis, how much the lamps will cost to make and then see if there is any financial advantage to be gained by using them; the second, which is adopted here, is to calculate how much the user can afford to pay for the lamp without the total cost of his lighting over any given period being increased, and then to see if it is possible to manufacture the lamp at this price.

The production of lamps with an internal reflector will obviously be more expensive than the production of the normal type lamps and the additional lamp expense incurred by the user due to the increased manufacturers' costs must be balanced against the saving on the purchase of the fitting. The cost of any lighting fitting can be spread over a number of years according to the expectation of life of the fitting and the cost per fitting year calculated. If the fitting be dispensed with then the lamp cost per year can be increased to cover the cost of the internal silvering, and the maximum amount of the increase without incurring the user in any extra cost will obviously be equal to the fittings cost per year. Against this increase in lamp cost, an allowance must be made to cover the cost of a lampholder and a simple protective cover, and it can

* The author is with the G.E.C. Ltd. This article is based on a paper originally presented at an Informal Meeting of the I.E.S. in London.

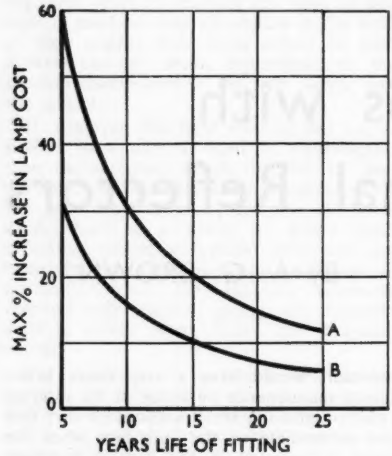


Fig. 1. 400-*watt HPMV lamp burning in fitting costing* £5 18*s.* 6*d.*
A = 1,500 *hrs./year.*
B = 3,000 *hrs./year.*

be assumed that the cover would enjoy the same life as the fitting would have done under the same circumstances. In this manner calculations can be made for various lives of the fitting and a curve can be obtained showing the maximum

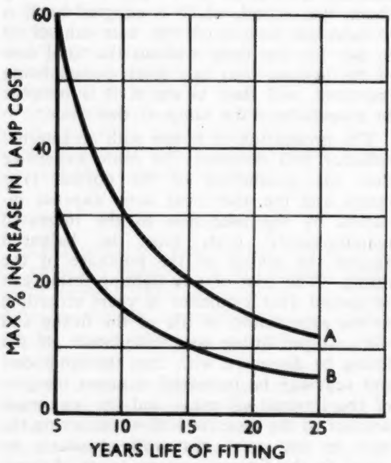


Fig. 2. 1,000-*watt HPMV lamp burning in fitting costing* £13 12*s.* 6*d.*
A = 1,500 *hrs./year.*
B = 3,000 *hrs./year.*

permissible percentage increase in lamp price against the life of the fitting for a particular number of burning hours per year.

Consider, for example, the case of an installation using 400-watt mercury lamps costing approximately £3, in fittings costing £6, where the lamps are burning 1,500 hours/year. The lamp, having a life of 3,000 hours, will last for two years, incurring the user in a lamp cost of 30s. per year. If the fittings were expected to last six years then the fitting cost per year would be 20s. If the fitting be dispensed with then the lamp cost can be increased by 20s., less the cost of a simple protective cover. Assuming this cover to cost 30s., and to last for six years, then

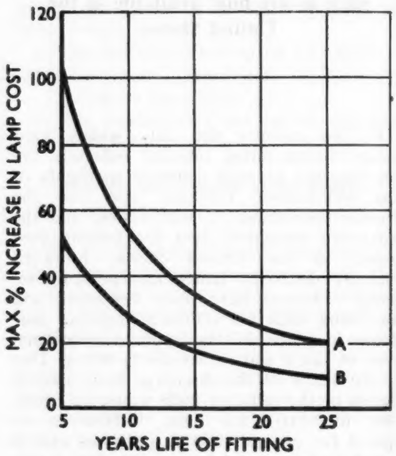


Fig. 3. 1,000-*watt HPMV lamp burning in fitting costing* £13 12*s.* 6*d.*
A = 1,500 *hrs./year.*
B = 3,000 *hrs./year.*
Assumed lamp life 5,000 *hrs.*

the cover cost per year is 5s. The annual lamp cost can therefore be increased by 15s. or 50 per cent. without incurring the user in any additional cost.

In a similar manner calculations can be made for various lives of the fitting and a graph can then be drawn showing the maximum permissible percentage increase of the lamp cost against the anticipated life of the fitting.

Fig. 1 shows such a curve for a 400-watt lamp costing £2 19s. operating in a dispersive fitting costing £5 18s. 6d. If the anticipated life of the fitting was 10 years then, by dispensing with the fitting, the lamp cost could

be increased by 16 per cent. if the lamp is used for 3,000 hours per year or 32 per cent. if used for 1,500 hours/year.

Fig. 2 shows similar curves for a 1,000-watt mercury lamp costing £8 burning in a fitting costing £13 12s. 6d.

The curves in Figs. 1 and 2 were based on a lamp life of 3,000 hours. It is well known, however, that under good conditions of infrequent switching far longer lives can be obtained from many high-pressure mercury vapour lamps. Fig. 3 shows the curves for the 1,000-watt lamp redrawn on an assumed lamp life of 5,000 hours. It can be seen that any increase in lamp life very much improves the case for an internally silvered lamp.

It is readily apparent from the accompanying curves that the life of the fitting is also of great importance in this calculation. Many of the better quality industrial discharge lamp fittings on the market to-day may well last for 20 years or more, and under those circumstances the use of lamps with internal reflectors could hardly be justified from an economic point of view. Considering the matter logically, however, do we really want a fitting to last 20 years? On looking through lighting catalogues of 20 years ago we more fully appreciate the technical advances made since that time. New and more efficient light sources have been developed and new fittings have been designed to use these sources to the best advantage. It is to be hoped, and the user has the right to expect, that long before another 20 years have passed new and more efficient light sources will have been developed making the present types with efficiencies of around 50 lumens per watt obsolete as far as industrial lighting is concerned.

With the high cost of electricity consumers will naturally wish to change to higher efficiency light sources as they become available, and this may well entail changing an expensive fitting long before 20 years' useful life have elapsed. In an industry where improvements and changes are continually being made, a fitting designed to last for 20 years or more must be regarded as a bar to progress or a thoughtless waste.

If the useful life of fittings is regarded as being about 10 years, then the permissible increase in lamp price for a reflector should be sufficient to cover the cost of internal silvering even assuming 3,000 burning hours per year, which is probably above average.

In addition to normal lighting applications, reflector mercury lamps may have several other applications such as photo-printing or ultra-violet display work.

Many manufacturing problems would be encountered, particularly perhaps in the manufacture of a colour-corrected mercury reflector lamp, but a lot of these problems have been overcome in the United States and there is no reason to suppose that British manufacturers could not produce a range of reflector lamps of as good, if not better, quality.

Lighting in U.S.A.

(*Continued from page* 356)

was the 5-ft. 80-watt lamp with nearly double the luminous output. With the higher illumination levels current in the United States one would expect the higher lumen output lamp to be used there; he asked if Dr. Harrison would like to comment on this.

Dr. Harrison said that the brightness of the British 5-ft. lamp would be regarded as too high in America, where the tendency was to keep the brightness down. He said there was a decided trend now towards the use of the 8-ft. lamp but the brightness was about the same as that of the 4-ft. lamp.

Mr. Howard Long, following up on Dr. Harrison's comments on the 40-watt lamp, said that in spite of their lower brightness they were not used unscreened whereas in this country installations of bare fluorescent lamps were not uncommon. Dr. Harrison said that with any new light sources mistakes were bound to be made. When the fluorescent lamps were first introduced installations of bare lamps were quite common and though bare lamps on high ceilings could still produce good installations it was generally considered in America that high brightness was objectionable and that lamps should preferably be totally enclosed and concealed from view.

One speaker said that in his experience lighting installations designed in accordance with the brightness ratios recommended in the United States were very dull and uninteresting. Dr. Harrison agreed that this might be so.

British Standards

The British Standards Yearbook for 1953 (British Standards Institution, British Standards House, 2, Park Street, London, W.1, price 12s. 6d.) contains an up-to-date record of the work of the Institution and lists B.S.S. current at March 31, 1953. This Yearbook is a useful source of reference.

Midlands I.E.S. Meeting

A brief report of the one-day meeting held in Nottingham on July 10.

At Nottingham University on July 10 the Midland Centres of the I.E.S. held a one-day meeting in which a number of members from the Midlands and London and a number of visitors took part. Two papers were given at which the President, Dr. W. J. Wellwood Ferguson, took the chair. During the morning the ladies present were conducted on a tour of the University and the halls of residence and in the afternoon they visited the Boots factory at Burton.

In his opening remarks the President said that the meeting was by way of an experiment and in arranging the meeting it was possible that the participating Centres had anticipated a future development of the Society whereby neighbouring Centres might combine to attract better papers and thus hold better attended meetings than was possible by small Centres acting alone. He said that considerable work had been put into the organisation of the meeting and he was sure that by the end of the day all who had taken part would agree that it had been well done and well worth while.

The President then introduced Prof. H. Cotton, head of the department of electrical engineering of Nottingham University, who gave his paper on "Colour in pictorial art."

After welcoming the I.E.S. on behalf of the University, Prof. Cotton said that whenever discussing a subject it is a good plan to start with a definition as it helps to fix one's ideas. "Art" as quoted in the Oxford dictionary is the application of skill to subjects of taste; skill applied to the arts of imitation and design; an occupation in which skill is employed to gratify taste or produce what is beautiful. "Artist" is a following of a pursuit in which skill comes by study or practice; one who cultivates one of the fine arts which please by perfection of execution. The emphasis, Prof. Cotton said, is on skill. The necessary skill not only involves a knowledge of the possibilities of a medium and the ability to exploit those possibilities, it also involves a knowledge of the limitations of the medium, and this is frequently forgotten.

"What are the qualities that make one work great and which are absent from a work which is unimportant?" In reply to his own question Professor Cotton suggested three. Firstly, a complete understanding by the artist of the medium he has chosen and evidence of this understanding in the finished work; secondly, evidence of a great demand on the time and the energy both physical and emotional of the artist; and thirdly, the ability to make such an impact on the beholder that, mentally or emotionally, or both, his life has been enriched. His criticisms of the "Unknown Political Prisoner" showed that it seemed to be lacking in all three. It showed no evidence of an expert knowledge of the medium, he said, for anyone can twist bits of wire by the aid of a pair of pliers. It does not represent any amount of labour, for we are told that a replica could easily be made in half an hour, and finally he stated that he had not heard of anyone who felt better for having seen it, and yet there must be some people who regard it as an important work of art for it has earned its maker a prize of £4,000.

In comparison Prof. Cotton had previously praised the work of sculptor Henry Moore, who, he said, used his understanding of the personality of stones to "make them speak," and whose work, although not representational of the sculptors of classical times, should not be discussed as nonsense because one may not be able to receive the artist's message.

Turning to the medium of the pictorial artist, Prof. Cotton went on to discuss the work of many painters both past and present, analysing their works in connection with medium, light, colour, etc. He drew special attention to the various methods artists used to obtain luminosity, such as the use of tempora when painting the human flesh or that of the reflecting power of a white wood panel instead of canvas. No painter is able to approach to true statement of Nature's colour, but the memory, probably quite un-

Members of the Organising Committee, including Mr. P. L. Ross (chairman) third from left, front row, with Prof. Cotton on his right and Dr. W. J. Wellwood Ferguson on his left.

consciously, corrects the painting and tends to give the impression of a more exacting brightness. Nevertheless, a considerable amount of work has been carried out into the brightness range, and with the aid of tables Prof. Cotton showed that in some scenes the ratio of the greatest to the smallest local brightness was as much as 5,000 to 1, whilst that attainable in various techniques of painting was never more than 50 to 1.

In conclusion, Prof. Cotton returned to the subject of "modern" art, and said that perfection of form, composition and technique were achieved hundreds of years ago, and it is therefore understandable that the modern artist should try to break away from tradition, not only because of the irrepressible urge to do so, but because it is not possible to climb higher than the highest point.

The discussion on Prof. Cotton's paper was opened by Mr. G. G. Palmer, of the Nottingham College of Art, and a vote of thanks to the author was proposed by Mr. W. J. P. Watson.

Lunch was taken in the refectory of the University, the guests including the Lord Mayor and Lady Mayoress of Nottingham and the Sheriff of Nottingham. The chair was taken by Mr. P. L. Ross, who was chairman of the committee responsible for the meeting. A toast to the City of Nottingham was proposed by Dr. Ferguson to which the Lord Mayor replied.

In the afternoon a paper entitled "Eye, Nerve and Brain" was given by Mr. H. Asher, lecturer in optics at the medical school of the University of Birmingham.

Mr. Asher said that in many ways engineers are a long way ahead of physiologists and psychologists and that it is often better in practical problems involving vision to follow engineering principles rather than to base action on the findings of physiological experiments. He said that the material of his lecture could have no direct application to illuminating engineering problems, but was intended rather to add to the general background of knowledge on which lighting engineers must draw in the production of original ideas.

The optical system of the eye suffers, he said, from almost every defect possible, including spherical and chromatic aberration. The mental image, however, is very much better than one would suppose possible. He then described in detail the construction of the eye and the function of the various nerves which convey the image to the brain

touching briefly upon colour vision. He also discussed the interaction of the various parts of the retina and carried out a number of interesting demonstrations to show how the eye can be deceived by contrasting brightnesses. He said that it is of great interest to know where the contrast and adaptation mechanism resides, whether it is in the eye or the brain; there is some evidence that contrast can occur in both eye and brain separately so that there may be one process of contrast which is physiological and one which is psychological. One encouraging feature of the work on vision is that lines of research which originally seemed entirely separate are now seen to be coming together.

The discussion on Mr. Asher's paper was opened by Mr. J. G. Holmes and a vote of thanks to the author was proposed by Mr. W. R. Stevens.

The proceedings were then brought to a close by the President who expressed the appreciation of all present of the interesting and stimulating papers which had been given. He also expressed thanks to the University of Nottingham for placing such excellent facilities at the disposal of the Society for the meeting.

During the evening an informal dinner was held at the Victoria Station Hotel in Nottingham. The toast of the I.E.S. was proposed by Mr. Asher who said that he was very pleased to have made the acquaintance of the Society which was obviously a body open to receive new ideas. The reply was made by the President who congratulated the organisers of the meeting and spoke of the benefits to be obtained from the informal contacts made at such meetings. A toast to the University of Nottingham was proposed by Mr. H. C. Weston to which Prof. Cotton replied. In conclusion the President, on behalf of the organising committee, made a presentation to Mr. K. J. Goddard and Mr. H. J. Slater, honorary secretary and treasurer respectively of the committee, for their work in arranging the meeting.

Correspondence

To the Editor, LIGHT AND LIGHTING

Dear Sir,—The July issue of LIGHT AND LIGHTING once again contains the usual gems of "Lumeritas." In particular my attention was attracted to his reference to "untied" illuminating engineers and a guaranteed living for them. I feel sure that "Lumeritas" has had a good look at recent correspondence from Messrs. Horniblow and Hemingway on the new trend of lighting technique and what the illuminating engineer should be and what he should know.

I have recently decided to terminate my interest in specialised lighting for buildings, factories, etc., and I have gone over to automobile lighting and allied subjects.

One of my reasons for taking this action is the complete lack of status of the present-day salesman-cum-lighting engineer who has each foot in separate camps but at the same time has no feet anywhere at all.

I sincerely feel that any lack of status in the work of the lighting engineer is due to his unwillingness and/or inability to move with the times and to decide to what field he really belongs.—Yours faithfully,

Cheltenham. BERNARD CORBETT.

BOOK REVIEW

"Daylight." By J. Swarbrick. Pp. xiv + 65; Figs. 42. *Batsford and The Wykeham Press. Price* 20*s.*

The author has already been responsible for three volumes entitled "Easements of Light," which deal with the subject of daylight chiefly from the point of view of those concerned with disputes regarding rights of light. In the present slender volume Mr. Swarbrick has widened his field to include a treatment of the nature, therapeutic properties and measurement, as well as the "legal protection" of daylight, and to speed him on his way he has good wishes expressed in a Foreword by Lord Horder, in two Introductory Notes by Sir Wm. Holford and by Prof. H. O. Corfiato respectively, and in a Preface by Dr. C. Roland Woods.

The first chapter includes history and archaeology, as well as the physics and physiology one would expect from the heading "The Nature and Therapeutic Properties of Daylight." It is interesting to learn that "until 1938 the true nature of the sun, the source of life-giving energy, was a matter of vague speculation" and that "invisible radiations that the eye cannot see but which can be seen on a photographic plate or on a fluorescent screen, are popularly called 'Dark Light' and occur largely in the infra-red wave-lengths . . . ." A few lines further on comes a reference to the use of infra-red detectors, followed by the intriguing statement, "It is therefore apparent that light and darkness are fundamentally the same thing," and this naturally leads to an exegesis of Ps. 139, v.12 (A.V.) (The darkness and the light are both alike to thee) which does not appear to have occurred to the theologians. As Mr. Swarbrick says. "The psalmist was not a nuclear physicist, but he uttered this profound truth more than 2,000 years before scientists proved that it was a statement of fact." Passing now to matters physiological, we learn with some astonishment that "It is commonly supposed that light is seen by the eye, but physiologists have proved that the eye and the optic nerves are mere receptors and that the sense of sight is due to the brain. If the eye could see things, without any co-operation by the brain, every prospect we look at would be upside down. By means of an inconceivably wonderful arrangement of the optic nerves the prospects that the retinae of the two eyes see upside down are reversed on their way to the brain. In a similar way the views that the two retinae see on the right side are transmitted to the left side of the brain, and the views that the two retinae reveal on the left side are conveyed to the right. In consequence we are able to see things as they are and not as the eyes alone would see them if they and not the brain possessed the sense of sight."

Chapter II deals mainly with the measurement of sky factors by the use of specially designed networks or diagrams, with particular reference to the author's photo-theodolite, and Chapter III with the determination of sunlight penetration into buildings. In these two chapters and in Chapter IV, "Regarding the Law of Light and Legal Practice in England," the author is on his own ground and the treatment is sound and clear.

There are two appendices giving the principles which underlie the construction of "calculating diagrams," the networks referred to previously. In Appendix II the statement in line 4 of the text is inconsistent with that in line 6; the latter is correct, the former an incorrect use of the word "illumination." In the title to Appendix I and elsewhere in the book there are references to "Lambert's Law" when what is meant is the cosine law of illumination. While it is true that Lambert enunciated both this and the inverse-square law, the expression "Lambert's Law," especially if unqualified, should be reserved for the law of emission from a uniform diffuser, for this law alone is not an almost self-evident consequence of the rectilinear propagation of light.

The book is well produced but there is no index. J. W. T. W.

Personal

Mr. C. J. W. Scott, of Crompton Parkinson, Ltd., has been elected Chairman of the Electric Lamp Manufacturers' Association for the 12 months ending May 31, 1954.

Mr. H. G. Towner, area manager for Venner, Ltd., is now at Court Cottage, Tithe-Pit Shaw Lane, Warlingham, Surrey (telephone Upper Warlingham 2519).

The retirement is announced of Mr. S. R. Bussey, specialist lighting fittings representative of the G.E.C., Ltd. Mr. Bussey had been with the G.E.C. since 1909.

Sangamo Weston Ltd. announce the appointment of Mr. H. A. Springer, contracts manager of the company, to their board of directors.

POSTSCRIPT

By "Lumeritas"

Last month's issue was unique in the history of this journal for its "make-up." Whether the Editor remembered the old saying that "one look is worth a thousand words" I know not, but it was certainly a happy idea to "cut the cackle" (including mine!) and present a pictorial account of Coronation lighting with a minimum of verbal accompaniment. No doubt lighting engineers would be interested in the technical and design data of some of the installations, but this can wait. A record of the scenes created was the immediate objective, and, to my mind, this was very well done.

The use of fluorescent lamps for street lighting is increasing, and I have seen some excellent new installations based on them. If street lamps must be visible, then, speaking as a motorist, I much prefer to see fluorescent lamps than any others because I find them less glaring. But, apart from this, the appearance of the lighted streets is, I think, generally more pleasing with fluorescent than with other forms of artificial lighting. In saying this, I do not mean that the lanterns and standards themselves are particularly pleasing; usually these are not things of beauty, nor are they when other lamps are used. But the disparity of our streets in the matter of lighting has also been increased with the coming of fluorescent street lighting, and this is not a feature to be welcomed. In the course of a comparatively short journey the roads traversed may include some illuminated by each of the now common light sources—gas, tungsten filament, mercury, sodium and fluorescent. This state of affairs will doubtless continue for many years yet. The writer of a recent article in the "Electrical Review" on "Lamps for Street Lighting," has expressed the view that, despite its advantages, fluorescent lighting of streets is not likely to become very widespread because of the capital cost involved. A correspondent contends, however, that the annual cost of fluorescent street lighting, "allowing for normal rates of capital repayment and interest," is closely comparable with that of mercury or sodium discharge lighting, and he pleads for a careful consideration of comparative costs when any new installation of discharge street lighting is projected, and that acceptability of the illuminant to the ratepayers—who have to foot the bill anyway—should be taken into account.

Fluorescent street lighting does not seem to have given rise to any of the odd fears and complaints of ill-effects which have sometimes followed the installation of fluorescent lighting in factories and offices. In particular, I have heard no mention of flicker or troublesome stroboscopic effects in streets illuminated by fluorescent lamps. It is well known that the sensitivity of the average person to flicker varies with the brightness and the size of the flickering field, i.e., the greater the magnitude of these factors (up to a certain limit) the higher must be the flashing frequency of an intermittent light before it appears to be continuous and free from flicker. For example, in some experiments on flicker described in the July issue of "Illuminating Engineering"—the journal of the American I.E.S.—the "critical fusion frequency" was found to vary from about 22 to about 40 cycles/sec. when the brightness of a 2-degree flicker-source and of its surrounds was varied from 1 to 50 ft.-lamberts. These frequencies at which fusion occurred are well below the flashing frequency of fluorescent lamps. Under suitable conditions, flicker is noticeable with lights which flash more than 40 times a second, but with properly installed fluorescent lighting operating normally I have never observed any flicker nor found anyone who claims to have done so.

This month's "gem" from the columns of the daily Press is the following letter: "Surely it is obvious that baldness most readily attacks men who spend most of their working time under electric light. The fact that women are spared supports this theory—their longer hair and more elaborate styles protect the roots from the rays. Any radiologist knows the dangers of his occupation. Tramps, sailors, manual labourers, are spared the risk." The ingenuous lady who wrote this is doubtless too young to have had opportunities for studying the comparative incidence of alopecia among the men and the Fannys by gaslight, though a little "research" would have shown her that hair restorers were much advertised before electric lighting became at all general.

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